Erection and Inspection of Iron and Steel Constructions

WRITTEN FOR THE USE OF

ARCHITECTS, ENGINEERS AND BUILDERS AND FOR CIVIL SERVICE CANDIDATES FOR THE POSITION OF INSPECTOR OF IRON AND STEEL

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PRICE, $2.00

PUBLISHED BY
THE CHIEF PUBLISHING COMPANY
NEW YORK
1913

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To my mother

Bella

to whose untired devotion I largely owe whatever little I may possess in education, kindness and intellectual ambition, this book is most affectionately dedicated.

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PREFACE

The purpose of this publication is three fold:

First: To present before practical builders some essential technical facts, necessary to a better understanding of the qualities and defects of Iron and Steel as used in construction work.

Second: To form a ready reference book for Architects, Engineers and Inspectors, for use in the field, in figuring the strength of beams, columns, and connections.

Third: It will prove a valuable aid to students in engineering and to candidates for Civil Service Examinations for the position of Inspector of Iron and Steel Constructions.

Some of the information following is extracted from excellent volumes on architecture, metallurgy, fabrication, designing, erection and superintendence. Much of the material, however, is entirely original, being based upon results of actual inspections made by the author in his former capacity.

Lupescu M. Bernfeld.

New York City, December, 1912.

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PART I

CHAPTER I.

Definitions and General Introduction.

STRESSES. Place a brick on end and rest on top of the brick a weight of 200 pounds. (Fig. 1) This weight causes a downward pressure against the brick. In the same time there is developed in the brick an internal resistance of 200 lbs. acting against the weight and keeping the same in equilibrium; otherwise the weight would crush the brick and move downward. The weight represents an external force acting upon the brick. The internal resistance developed in the brick by this weight is called a "stress." We can therefore say, that: "A **stress** is an internal resistance which balances an external force."

An exterior force acting on a body tends to produce a deformation or change in the shape of the body. We call "**Strain** or deformation" the change in shape or the distortion caused in a body by an external force acting upon it.

Three kinds of simple or direct stresses may be produced by external forces; these are: Tension, caused by forces stretching or tending to pull a body apart. Compression, caused by forces tending to push together or shorten a body. Shear, caused by forces tending to cut across.

In all cases **unit stress** is the stress per unit area. For instance:

If a brick 2x4x8$\frac{1}{4}$ in. stands on one end and a weight of 240 pounds is rested on it, the unit compressive stress equals 30 pounds per sq. in.

In the same way, if a weight of 2,000 pounds is hung from a rope having a cross-section of $\frac{1}{2}$ sq. in., the unit tensile stress equals $2{,}000 \div \frac{1}{2} = 4{,}000$ pounds per sq. in.

Consider two plates riveted together, as in Fig. 2. When the plates are in tension, they tend to shear the rivet or cut it across the area between the two plates. Let the tension in each plate be 2,209 lbs. The cross-sectional area of a $\frac{3}{4}$ in. rivet is $3.14 \times \text{diam.} = 3.14 \times \frac{3}{4} = .4418$ square ins. The total shear tending to cut the rivet across is 2,209 pounds. This shear divided by the cross-section resisting it is the unit shear. We therefore have: Unit shear$=2209 \div .4418 = 5{,}000$ pounds per square inch.

Elastic Limit and Ultimate Strength. When a gradually increasing force is applied to a bar, the deformation of the

bar increases in proportion to the force within certain limits. For instance: If a steel bar one sq. in. in cross-section and 100 in. long is subjected to a gradually increasing tensile force, it elongates as shown in this table:

with a tension of 6000 lbs. the bar elongates	.02 in.
12000 "	.04 "
18000 "	.06 "
24000 "	.08 "
30000 "	.10 "
36000 "	.12 "

Notice that the elongation was so far proportional with the stress; when the stress was doubled, the deformation also

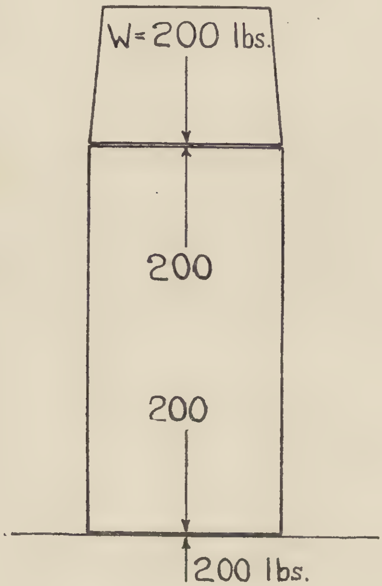


Fig. 1.

doubled. However, with a tension of 42,000 lbs. the bar elongates .15 in. or .16 in., or in other words, the deformation increases faster than the force applied.

Elastic Limit is that unit stress at which the deformation begins to increase in a faster ratio than the stress.

When a body is stressed below the elastic limit, upon removing the force, the body will spring back to its original shape and length. When a body is stressed above the elastic limit, upon removing the force the body does not acquire its original shape and length, but it remains permanently de-

formed or it acquires a permanent **Set.** This shows that stressing a body beyond its elastic limit is injurious to the elasticity and strength of the body and should never be allowed in practice.

Returning to the above illustration, if the tensile force is

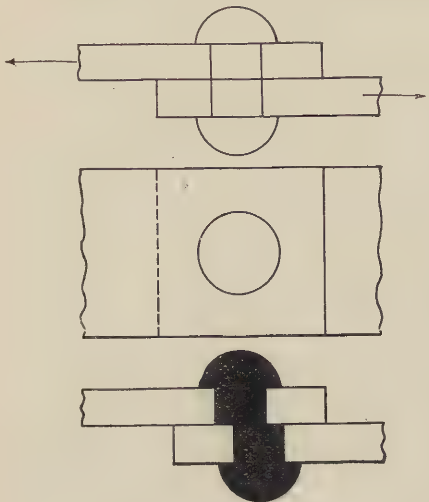


Fig. 2—Single Shear.

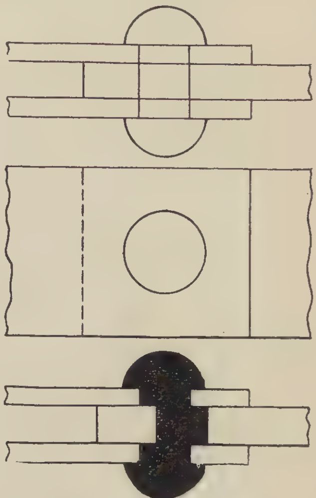


Fig. 3—Double Shear.

increased beyond 42,000 lbs., the bar will elongate more and more until finally rupture of the bar takes place.

Ultimate strength is the unit stress which occurs just before rupture, and it is the highest unit stress that a bar can bear.

The ultimate strength varies with different materials, and is from two to four times the elastic limit. For some materials the ultimate strength is higher in compression than in tension.

Unit strain or unit deformation is the deformation per unit length. For instance, in the above table, with a stress of 30,000 lbs. the total elongation in 100 in. was .10 in. and the unit strain or elongation per inch of length of the bar was $.10 \div 100 = .001$ in. Since up to the elastic limit the deformation is nearly uniform throughout the bar, the elongation in any portion of the bar, i. e., in 8 in. will equal $8 \times .001 = .008$ in.

Modulus of Elasticity is a number which results by dividing unit stress by unit strain and is a constant number for stresses below the elastic limit. For instance, in the last table with 6,000 lbs., per sq. in. of bar area or with a unit

stress of 6,000 lbs. per sq. in. the unit elongation was .0002 in. and the modulus of elasticity for this bar is equal to $6{,}000 \div .0002 = 30{,}000{,}000$.

With a unit stress of 12,000 lbs. per sq. in. the unit elongation = .0004 in. and this gives a modulus of elasticity equal to $12000 \div .0004 = 30$ mil. This shows that the modulus of elasticity is constant below the elastic limit. The modulus of elasticity is used in figuring out deformations when the stresses are given and vice-versa.

Factor of safety is the number obtained by dividing the ultimate unit strength by the actual unit stress. For instance: A one inch square steel bar supports in tension a load of 5,000 lbs.. If the ultimate strength or breaking load is 65,000 lbs. per sq. in. then the factor of safety $= 65000 \div 5000 = 13$.

The factors of safety must be greater for varying loads than for steady loads. In table on page 5 usual factors of safety are given for steady loads such as in buildings; for varying stresses as in bridges and for shock as in machinery.

Working Unit Stress is the ultimate strength divided by the factor of safety. For instance: Let four be the factor of safety for steel fixed by law or by specifications. If the ultimate strength in tension is 65,000, the working or allowable unit stress equals $65000 \div 4 = 16250$ lbs. per sq. in. A flat bar 2 in. $\times$ 1 in. section for instance, will not be loaded in tension with more than $2 \times 16250 = 32500$ lbs.

The working unit stresses are higher for dead loads than for variable or moving loads or for impact. The working stress must always be considerably lower than the elastic limit to prevent injury to the material through over-straining.

Coefficient of linear expansion is the increase per unit length of a bar when the temperature of the bar is increased by one degree Fahrenheit. For instance, a steel bar a foot long at 40° F. becomes 1.0000065 ft. at 41° F. The increase per degree of a unit length is therefore .0000065 for steel. This number is the coefficient of linear expansion for steel.

The definitions given in this chapter are of great importance and the reader is advised to thoroughly master them before proceeding any further.

CHAPTER II.

Practical Problems on Stresses and Strains.

To further illustrate the meaning of the various terms defined so far and the relations existing between them, several practical problems are here given. In all problems that follow the values given in the following table shall be used:

	Pounds per cu. ft.	Melting point Fahrenheit	Elastic Limit pounds per sq. in. Tension	Compression	Ultimate Strength in pounds per sq. in. Tension	Compression	Shear
Cast Iron	450	2000°F.	6000	20000	20000	90000	20000
Wrought Iron...	480	3000°F.	25000	25000	50000	50000	40000
Steel............	490	2500°F.	35000	35000	65000	65000	50000

	Ultimate elongation per cent.	Coefficient of expansion	Modulus of elasticity	Factors of Safety Steady loads	Varying loads	Shocks
Cast Iron	.5	.0000062	15 mil.	6	14	20
Wrought Iron...	30.	.0000067	25 mil.	4	6	10
Steel............	25.	.0000065	30 mil.	4	6	10

1. A square steel bar 2 in. on each side is subject to a tension of 80,000 ℔s. To find the unit tensile strength and the factor of safety.

Area of cross-section of bar $=2\times2=4$ sq. in. Unit tensile stress $=80000\div4=20000$ ℔s. per sq. in. The factor of safety equals ultimate strength per sq. in. given in the table as 65000, divided by the actual unit stress; hence: Factor of safety $=65000\div20000=3.25$ or a little over 3.

2. A round cast iron bar 2 in. diam. carries in tension 18850 ℔s. Find the unit tensile strength and the factor of safety. Area of cross section of bar $=.7854\times$diam.$\times$diam.$=$ $.7854=2\times2=3.14$ sq. in. Unit tensile stress $=18850\div3.14$ $=6000$ ℔s. per sq. in. approximately. Factor of safety $=20000$ $\div6000=3\ 1/3$. As the factor of safety for cast iron is generally not less than 6, the bar is unsafely loaded.

3. A cast iron block $12 \times 12 \times 2$ rests flat on a concrete pier. A column erected on top of this block carries 28800 lbs. Assuming that the block distributes the column load uniformly upon the concrete pier, find the pressure in lbs. per sq. in. on top of the pier. Area of bottom of block $= 12 \times 12 = 144$ sq. in. Unit pressure on concrete $= 28800 \div 144 = 200$ lbs. per sq. in.

4. A wrought iron square bar is to carry in tension 40,000 lbs. with a factor of safety of five. Find its cross section. Ultimate strength for wrought iron in tension = 50000 lbs. per sq. in. Since the factor of safety is five, the allowable working load $= 50000 \div 5 = 10000$ lbs. per sq. in.

Total required area = 40000 lbs. ÷ 10000 lbs. = 4 sq. in.

The bar will therefore be a 2 in. square wrought iron bar.

5. A square steel block is to carry a column load of 115,200 lbs. The block rests on a concrete pier. Find the area of the block so that the pressure upon the concrete pier shall not exceed 200 lbs. per sq. in. Ans.: The block must be not less than 2 ft. — 0 in. × 2 ft. — 0 in. on bottom.

6. Find the diam. of a round steel bar to carry in tension 240,000 lbs., with a factor of safety of four. Ans.: 4.3 in., Use a bar 4 5/16 in. diam.

7. A cast iron square block is to carry 210,000 lbs. in compression. The allowable working stress is 15,000 lbs. Find the area of the block and the factor of safety. Ans.: Area = 14 sq. in.; factor = 6.

8. A square steel block is to carry 280,000 lbs. in compression. What should be its size in order that the unit stress may be one third of the elastic limit? Ans.: 24 sq. ins., or a square about 5 in. × 5 in.

9. A bar of cast iron 3 in. diameter ruptures under a tension of 141,372 pounds. What is its ultimate strength in pounds per sq. inch? Ans.: 20,000 lbs. per sq. in.

10. A load of 250,000 lbs. is to be carried in tension by means of a round bar. If the factor of safety is five; design a cast iron round bar to support the above load. Design also a wrought iron and a steel round bar, using the same factor of safety. Ans.: Diameters are 8.91 ins. for cast iron; 5.64 ins. for wrought iron; 4.95 ins. for steel.

11. What force will be required to rupture in tension a ¾ in. round steel bar? Ans.: 28,717 pounds or about 14 tons.

12. A cast iron bar one square inch in cross-section weighs 3.1 lbs. per foot. Find the length of a vertical bar

which ruptures under its own weight when hung on its upper end? Ans.: 6450 ft.

13. In a shearing machine a flat steel bar 2 in. × ½ in. was sheared exactly at right angles to its length. Find the shearing force? Ans.: 50,000 pounds or about 25 tons.

14. Find the ultimate strength in shear for a ¾ in. diam. steel rivet, also ⅝, ½ and ⅜? Ans.: 22,090 lbs.; 15,340 lbs.; 9820 lbs.; 5525 lbs.

15. The allowable shearing stress on steel rivets is 10,000 lbs. per sq. in. What is the factor of safety for shear? Ans.: 5.

16. How much load could four ¾ in. steel rivets carry in direct shear with a factor of safety of five? Ans.: 17,672 pounds or 8½ tons.

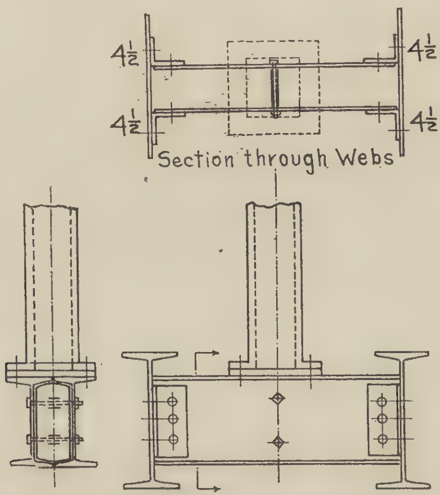


Fig. 4—Cast Iron Column resting on two Steel Beams.

17. A cast iron column rests in the middle of two 12 in. steel beams, 6 feet long (Fig. 4). If the beams get an equal share of the load and the column carries 18 tons how many ¾ in. bolts are required in each end connection of the two 12 in. beams? Ans.: As shown in the figure, there will be a load of 4½ tons or 9,000 pounds at the end of each beam. A ¾ in. bolt will carry in shear 70% of the amount carried on a ¾ in. shop rivet, or 70% of 4418 = 3000 pounds approximately. It will, therefore, be necessary to provide not less than three ¾ in. bolts in the ends of each beam.

18. A derrick rests at the middle of two 15 in. beams. There are two temporary ¾ in. bolts in each end of each beam. Should the derrick be used to hoist 16 tons of steel at once? Explain fully? Ans.: The cross-sectional area of a ¾ in. bolt is .4418 sq. in. The ultimate shearing strength for steel bolts = 50,000 ℔s. Using a factor of safety = 6 on account of varying loads used with derricks, we get: unit working stress=50,000÷6=8333 ℔s. per sq. in. and 8333× .4418=3680 lbs. per ¾ in. rivet The load for ¾ in. bolts = 70% of 3680 = 2576 ℔s. per ¾ in. bolt For two ¾ in. bolts

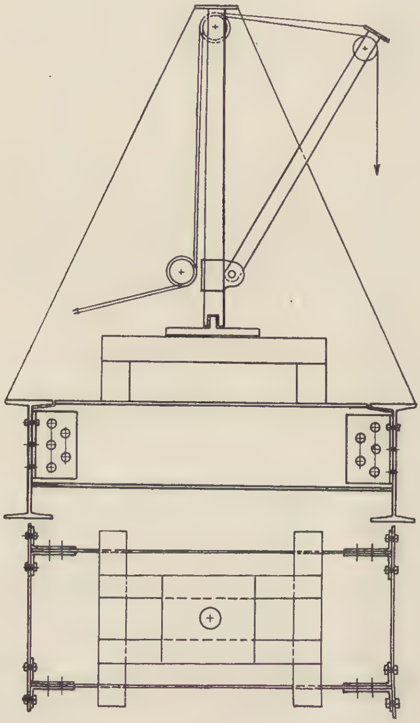


Fig. 5.

you get 2×2576=5152 ℔s. The load at each end of beams equals four tons or 8000 ℔s. The derrick, therefore, should not be used for 16 tons at a time. To allow for shock and overloading, all the bolt holes in ends of beams should be filled in with good temporary bolts in all connections under and near the derrick.

19. A steel rod is to carry a stress of 32,500 lbs. in tension or compression. Find its diameter when used in a bridge as a hanger, when used in a building as a tie, and when used as a piston rod in a steam engine? Ans.: The ultimate strength for steel in either tension or compression is 65,000 lbs. per sq. in. For bridge work where the loads are varying, use a factor of safety of six. In building work with practically steady work, use a factor of four. When the rod is subject to shocks, as in an engine, use a factor of safety of ten. The answers are: 2 ins.; 1⅝ ins.; 2 9/16 ins.

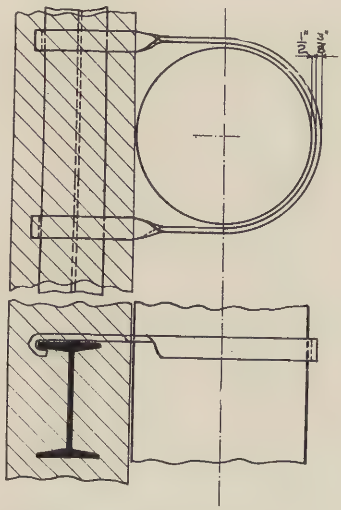


Fig. 6—Steel Flue and Anchor.

20. A steel bar 2×½ inches in section is ruptured under a tension of 64,000 lbs. What tension will rupture a 2×1¼ in. bar of the same material? Ans.: 160,000 pounds.

21. What tensile force is required to stretch a wrought iron bar 4×¾ from 25′—0″ to 25′ and 5/16 in.? Ans.:

We have: $\text{Modulus of elasticity} = \dfrac{\text{Unit stress}}{\text{Unit strain}}$

From which:

Unit stress = Modulus of elasticity × unit strain

and

$\text{Unit strain} = \dfrac{\text{Unit stress}}{\text{Modulus of elesticity}}$

For wrought iron the Modulus of elasticity = 25,000,000. The elongation in 25 ft. is 5/16 in. The unit elongation

or elongation per one inch = 5/16 ÷ 300 ins. = 1/960 in. and this is the unit strain.

Unit stress = 25,000,000 × 1/960 = 26,042 lbs. per sq. in.

Area of cross section of bar = 4 × ¾ = 3 sq. in.

Required tensile force = 3 × 26,042 = 78,126 lbs.

22. Find the compressive force which will shorten a block of cast iron 8 inches square from 4 ft. to 3 ft. 11¾ ins. Ans.: 5,000,000 lbs.

23. Find the unit stress which will stretch a steel bar one-tenth of one per cent. of its length. Ans.: 30,000 lbs. per sq. in.

24. What tensile force is required to stretch a steel bar 8 in. by ¾ in. from 30 ft. to 30 ft. and ⅜ in.? Ans.: 187,500 pounds.

25. A steel bar 12 in. by ¾ in. and 28 ft. long was stretched in length to 28 ft. and ½ in. Find the tensile force. Ans.: 401,600 lbs.

26. A steel block 6 in. by 6 in. and 4 ft. long was shortened under compression to 3 ft. 11⅝ in. Find the unit strain, unit stress, total stress and per cent. shortening. Ans.: Unit strain = .0078 in. per in. of length. Unit stress = 232,000 lbs. Total stress = 843,000 lbs. Per cent. shortening, 78/100 of 1 per cent.

27. A steel bar 10 ft. long at 32° F. is heated to 500° F. Find the change in length due to expansion.

Ans.: Elongation per foot per 1° F. = .0000065; elongation per 500° — 32° or 468° F. = .0000065 × 468; elongation per 10 ft. = .0000065 × 468 × 10 = .0304 ft. or nearly ⅜ in.

28. A vertical boiler flue 20 stories high is used to carry away furnace gases at a temperature of 500° F. Find the total expansion from 60° F. to 500° F. assuming each story 12 ft. — 6 in. high. Ans.: 8 9/16 ins. approximately.

29. An outside steel flue 4 ft. diam. and 250 ft. high is used for gases varying in temperatur from 60° F. to 500° F. The flue is kept in place at each story by means of flat 2x⅜ in. steel straps. The straps are larger on one side by ½ in. Find the expansion across the diameter. (Fig. 6).

Length of circumference = 3.14 × 48 in. = 150.7 in. approximately.

Expansion of circumference per degree F. = 150.7 × .0000065 = .0009795 ins. or, say, .00098.

Expansion of circumference for (500-60)° = .00098 × 440° = .431 ins.

Length of new circumference at 500° = 150.7 × .431 = 151.13 ins.

Length of new diameter = 48.13 ins.

The expansion in diameter is therefore about ⅛ in. and the ½ in. clearance is not necessary, the hoop being able to resist the effect of this expansion, especially that the hoop will also expand to a certain extent. Flue straps should be made tight against the face of the flue.

30. A steel column is so placed in the boiler room of a building that it cannot expand. The column is 18 ft. long. Find the additional unit compression caused in this column by a change of temperature from 60° F. to 160° F.

If the column was free to expand, the change in length for 100° F. or from 60° F. to 160° F. would be equal to 18 ft. × 100° × .0000065 × 12 in. = .1404 in.

The force required to stretch this column .1404 in. is equal to the additional compression caused by not allowing the column to expand.

Expansion per inch length $= \dfrac{.1404}{18 \times 12} = .00065$ in. = unit strain.

Unit tensile stress causing this expansion equals 30,000,000 × unit strain = 19,500 lbs. per sq. in. This load comes on the column in addition to its load at 60° F. In general, however, structures expand as a whole and this reduces the effects of expansion upon any one column.

31. What force is required to punch a 13/16 in. hole in a ⅜ in. steel plate? Also a 9/16 in. hole in a 5/16 in. steel plate?

Ans.: Circumference of a 13/16 in. hole = 2.55 in. Area to be sheared by the edges of the punch when passing through a ⅜ in. plate = 2.55 × ⅜ = .96 sq. in. Shearing force = 50,000 lbs. per sq. in. × .96 = 47,900 lbs. Similarly for a 9/16 in. hole in a ⅝ in. plate the shearing force will be 27,500 lbs.

CHAPTER III.

The Manufacture of Iron and Steel.

CAST IRON.

Cast Iron was first made in England at the beginning of the fifteenth century.

Definition. Cast iron is a product of the blast furnace; it is iron which is not malleable and which is produced by a process involving fusion.

Manufacture. All iron is obtained from iron ores. The most common ores used for this purpose are:

Hematite or red iron ore, containing about 70% iron.

Limonite or brown iron ore, containing about 60% iron.

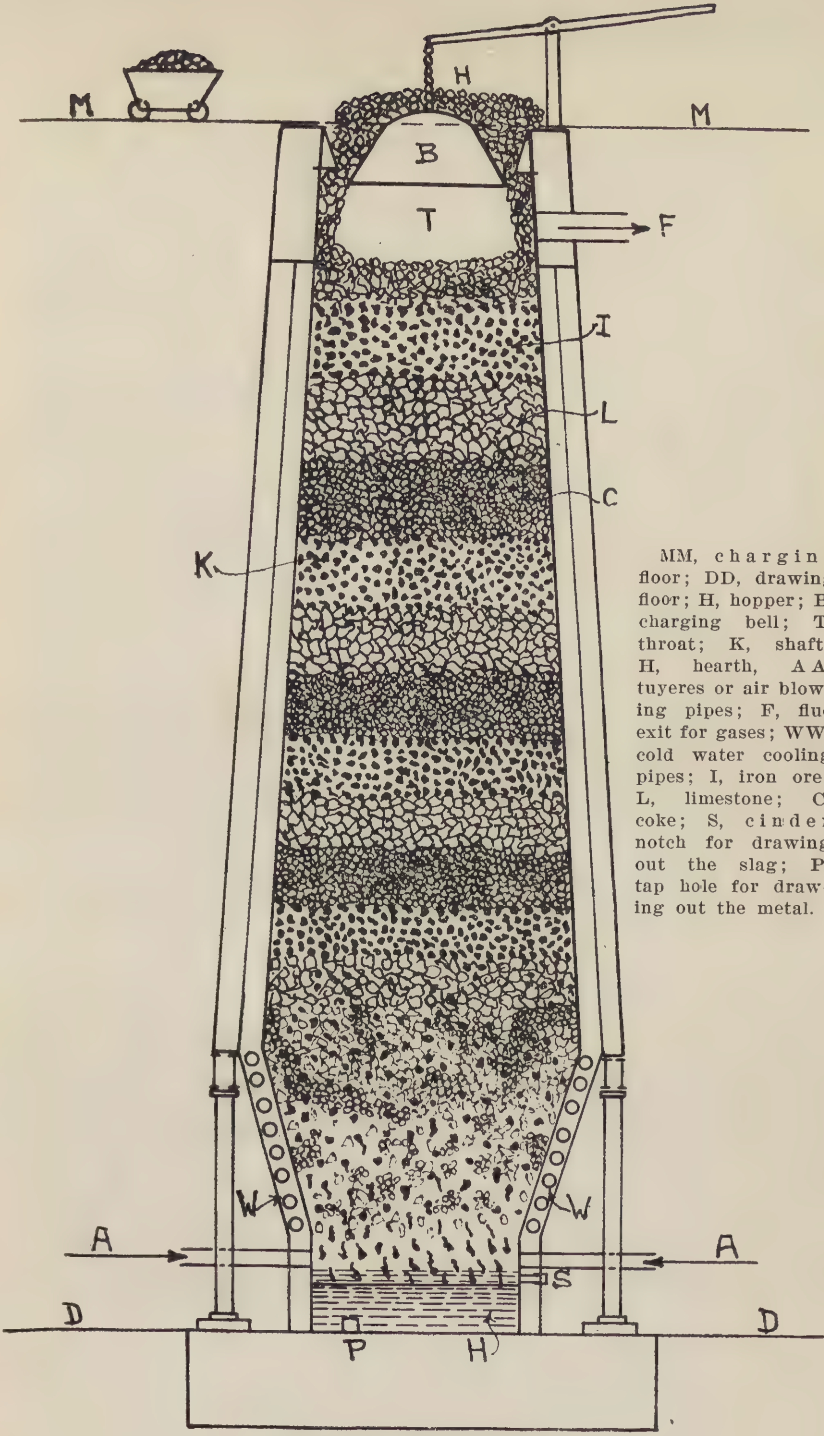
Magnetite or black iron ore, containing about 60% iron.

In addition, the ores contain various impurities, like alumina, manganese, phosphorus, silica, sulphur, etc. Part of these impurities separate from the iron and go into the slag during the process of melting the ores in the blast furnace.

The product of the blast furnace is allowed to flow into channels dug in sand, where it cools off. The main channel is the "sow," while the branch channels are called the "pigs." Hence the name of pig iron. This pig iron is remelted in a cupola and poured into moulds forming castings.

Classifications. Various grades of cast iron may be classified as follows:

		Names	Properties and Uses:
Pig Iron (Cast Iron)	1. Foundry Pig (Gray Cast Iron) Contains 6% to 4% Carbon.	No. 1 Gray No. 2 Gray No. 3 Gray forge	Dark gray fracture with metallic lustre and large crystals Specific gravity 7.1 to 7.2 Turns easy; soft and tough. Used for castings.
	2. Forge Pig (White Cast Iron) Contains 4% to 2% Carbon.	No. 5 White No. 4 Mottled	Light gray to silver white fracture and small crystals. Specific gravity 7.2 to 7.4 Hard to turn and brittle. Used for making wrought iron and steel.



MM, charging floor; DD, drawing floor; H, hopper; B, charging bell; T, throat; K, shaft; H, hearth, A A, tuyeres or air blowing pipes; F, flue exit for gases; WW, cold water cooling pipes; I, iron ore; L, limestone; C, coke; S, cinder notch for drawing out the slag; P, tap hole for drawing out the metal.

Fig. 7—The Blast Furnace.

Nos. 1 and 2 are used exclusively for foundry purposes. No. 3, for both foundry and rolling mill; finally, Nos. 4 and 5, for the rolling mill only.

Mottled iron is iron with a white background, dotted with spots of graphitic carbon.

Properties. In addition to carbon cast iron may contain about five per cent. of impurities like silicon, manganese, phosphorus, sulphur, etc.

The gray cast iron is used for castings. The darker grades of gray cast iron make the smoother castings, but are more brittle. The lighter grades of gray cast iron make tough castings and very often contain blow holes.

The white cast iron is hard, brittle and difficult to work, while the gray cast iron is soft, tough and easily worked. A fracture of good gray cast iron shows a light blueish gray color, a close grained texture and considerable metallic lustre.

A fracture of poor cast iron presents a mottled surface, with patches of darker and brighter iron, or it may show crystalline patches. Air holes may also be present in fractures of very bad specimens.

The quality of cast iron may be improved by long continued fusion and by repeated melting up to about twelve times. Cold blast pig gives stronger iron, but more expensive than hot blast pig.

Effects of Impurities. Carbon in cast iron decreases the specific gravity and the melting point. Other effects have been given under classification.

Manganese increases hardness and shrinkage, it also increases the percentage of carbon that the iron may hold into combination.

Phosphorus is readily taken up during the smelting process. Less than one per cent. of phosphorus in cast iron is beneficial, as it increases the fluidity and lessens the shrinkage. Over one per cent. of phosphorus seriously weakens the iron.

Silicon in small quantity will usually increase the strength of the cast iron. A large amount makes the iron brittle and weak.

Sulphur comes into the iron from the ores and from the coal used in the smelting process. Sulphur in castings should not exceed half of one per cent. Sulphur increases chill and shrinkage and decreases the strength, rendering castings unsound.

Common Defects in Cast Iron. Blow holes and honeycomb are defects caused by confined air and may render castings unsound. Cavities and holes are caused by the

collection of foundry dirt and other impurities and by unequal contraction during cooling. Internal stresses due to unequal contraction of the metal during cooling will often cause rupture, especially while the casting is struck a few sharp blows. Internal stresses may be avoided during the casting process by uncovering the thick parts first, so that they may cool just as quickly as the lighter parts. Other things being the same, the longer the cooling period the better the castings.

Following defects are often found in cast iron columns:

1. Unequal thickness, due to the shifting of the core before the metal is poured into the mould.

2. Shrinkage cracks, due to unequal contraction during cooling.

3. Warping and bending, caused by unequal contraction during cooling or by handling the columns before they have sufficiently cooled.

4. Cold shuts. In long castings requiring the metal to be poured from both ends in the same time, it often happens that the metal becomes too much chilled to properly mix and unite. This results in the formation of weak seams, known as "cold shuts."

The surface defects of cast iron are swells, scales, blisters, cold shuts, etc.

Inspection of Cast Iron. The work of inspecting iron in general may be divided as follows:

a. Laboratory examination and tests.

b. Mill inspection.

c. Field inspection.

Laboratory Inspection of cast iron consists in examining several test-bars poured from each melt. These test-bars are poured alternately before and after the casting is poured. About one test-bar for each ton of castings is generally sufficient.

Test-bars for tensile strength are about eighteen inches long, and usually turned down in a lathe in order to remove the exterior scale and enable a careful measurement of the diameter. They are then subject to increased tension in a testing machine until rupture occurs. The elongation of the bar is recorded for the various applied tensile stresses. Test-bars for bending cast iron are usually 3 inches wide by 1 inch thick, and are either 14 inches or 26 inches long; they are placed on supports 12 or 24 inches apart, with the narrow side vertical, and loaded on the center until broken. The deflection as well as the breaking load are noted.

The Shop Inspection of structural cast iron, like bases, columns, etc., is very similar to the field inspection, and both will be treated together in a future chapter. We will make mention, however, with regard to the shop inspection of cast iron water pipes.

Shop Inspection of Cast Iron Water Pipes. These are first subjected to a surface examination. Pipes with visible honeycomb and serious sand holes and blow holes are at once rejected. The same thing applies also to pipes with swells, scales and blisters on their interior faces. Honeycomb when not visible is easily located by the dull sound given by the pipe on tapping it with a hammer. The pipe is next subjected to a hydraulic pressure about twice as high as the pressure under which the pipe is to be used. While under pressure the pipe is carefully tapped all over with a hammer to discover air holes, flaws, etc. Each cast iron pipe has stamped on it the weight per foot. The weighing and marking of each piece is also inspected. All defective pipes are rejected.

Advantages of Cast Iron. Cast iron has a high compressive strength, is durable and little affected by corrosion; it can be cast readily in many useful shapes, and is cheaper than steel. Cast iron retains its rigidity at a red heat. For these reasons cast iron is used for column footings, columns, water pipes, bed plates for machinery, boilers, etc.

Disadvantages of Cast Iron. Cast iron is brittle, has a low tensile strength, and a low ductility and elongation. It is not so homogenous as steel and is therefore less reliable; it also snaps under the action of water in fires, when the iron is red hot. Cast iron in building work gives connections which cannot be riveted, and must be bolted, thus causing lack of rigidity. For these reasons cast iron should not be used where subject to tensile stress, heavy vibration, shocks or impact.

WROUGHT IRON.

Wrought iron is the oldest known form of iron. It has been found in the pyramids of Egypt, and has probably resulted at first from the action of fire upon nearly pure iron ore.

Definition. Wrought iron is metallic iron which has been manufactured by any process without fusion, and which contains less than 0.25 per cent. carbon.

Manufacture. At present wrought iron is generally manufactured from forge pig by a method known as the

puddling process. The pig iron is subjected to the oxidizing flame of a blast in a reverbatory furnace. Here the iron loses some of its impurities, through oxidation, and becomes soft like a paste. Operators known as puddlers, using special rakes, form this iron into paste-like balls called puddle balls or blooms, weighing about eighty pounds each. Each ball is then passed through a squeezer to expel cinder and part of the slag; then the ball is rolled into a "muck bar." Muck bars are cut to length, laid in piles, reheated, and rolled to "merchant bars." These are again cut to length, laid in piles, reheated, and rolled, giving "best iron." If the process is again repeated and the best iron is rolled once more, a grade known as "best best iron," or double refined iron, is produced.

Properties. Wrought iron is a malleable metal, can be forged and welded, and will stand shocks. It can not be tempered, and can not be melted, except with great difficulty. Good wrought iron is tough and has a fine fibrous and close texture; if subjected, however, to repeated shocks and excess loads around the elastic limit, the texture changes from fibrous to crystalline, with a decrease in the strength of the metal.

Best iron is about ten per cent. stronger than the merchant bar, due to the second rolling.

Cold rolling decreases the ductility and the ultimate elongation and increases the elastic limit and the ultimate strength. The strength also increases with a higher percentage of carbon.

Annealing decreases the ultimate strength and increases the elongation.

The fracture of good wrought iron is fine, fibrous and close, with small crystals of uniform size and color, and with a silky lustre. The metal has a leaden gray color. The fracture of poor wrought iron shows coarse crystals, loose, open and blackish fibres and blotches of color. Flaws in the fractured surface indicate that the reheating, rolling and welding processes were imperfectly carried out.

Wrought iron high in phosphorus is brittle when cold, hence the name, "cold short." Wrought iron containing sulphur, arsenic and other impurities, is known as "red short," and will crack when bent at a red heat. Red short iron cannot be welded.

Common Defects in Wrought Iron. 1. Poor material, shown by a fracture with coarse crystals and loose fibres.

2. Flaws in the fracture, indicating "red short" iron.

3. Bright crystalline fracture and discolored spots, indicating "cold short" iron.

Inspection of Wrought Iron. Tests. The usual tests for wrought iron ore are as follows:

1. Cold bending test: A square bar ¾″ on each side and about 15″ long is bent cold by means of pressure or with a hammer, to an angle of 90° in a curve whose radius is equal to twice the thickness of the bar. Rivet iron is bent on itself or through an angle of 180° while cold. No cracks should result. Wrought iron breaking under this test lacks both ductility and strength.

2. Hot bending test: Iron which is to be worked hot must bend sharply to 90° at a working heat without fracture. Iron showing cracks under these conditions is "red short," or high in impurities, and cannot be welded.

3. Nicking and bending: Specimens upon being nicked on one side and bent should show a fracture nearly fibrous.

4. Tensile strength is determined with a testing machine from test pieces, usually about 18″ long by 1″ wide, cut from the full-sized bar after the material is rolled. The thickness of the test piece will therefore be the same as that of the finished bar. The various stresses and the corresponding elongations are recorded.

5. In comparing several samples of wrought iron it is sometimes found convenient to multiply the tensile strength of each specimen by the corresponding ultimate elongation. The resulting product is a measure of the work required to rupture the bar. The best specimen will correspond to the highest product obtained in this way.

Advantages. Wrought iron is a durable material, and can be readily worked into a large variety of forms when heated. Pure wrought iron is less affected by corrosion than steel. Unlike cast iron, wrought iron is malleable, and can therefore be made into plates. It is ductile, or can be made into wires, and it is about equally strong in tension and compression. For these reasons wrought iron may be used in places where subject to alternating compressive and tensile stresses, provided the unit stress is not excessive. It was much used for truss-members, columns, beams, girders, wall anchors, rivets, etc. At present it is largely replaced by soft steel.

Disadvantages. Wrought iron is not as homogenous as steel, cannot be melted without difficulty, and is less stiff than steel, i. e., a wrought iron beam will deflect more than a steel beam of similar length and cross-section under the same load.

Wrought iron is also less strong than steel. For all these reasons it is not used where great strength is required.

Even in ornamental iron work the lower carbon steel or soft steel has largely replaced wrought iron, due to the cheapness and the capability of the soft steel of being readily worked into various desired forms.

STEEL.

Steel, produced by a special method little used at present, was known from very old times and manufactured in Asia, where it was used especially for making high grade tools and war weapons. The Bessemer steel of to-day was invented by Bessemer in England.

Definition. Steel is iron which is malleable and which is produced by any process with fusion.

Manufacture. Steel contains less than two per cent. carbon, and can be manufactured from wrought iron by adding carbon to same; or from cast iron by removing part of the carbon. The most common processes of steel manufacture at present are as follows:

The Crucible Process. Blister steel or impure wrought iron is mixed with some flux and carbon in a closed crucible. The mixture is fused in the absence of air for several days. The best tool steel is thus obtained.

The Open Hearth Process. Pig iron is fused in a Siemens furnace with enough wrought iron scrap to reduce the percentage of carbon to any desired amount. Most of the structural steel used for buildings and bridges is manufactured by this process.

The Bessemer Process. Air is blown through molten pig iron in a Bessemer converter until all the carbon is burned out. Then the desired percentage of carbon is obtained by throwing into the converter a sufficient amount of "Spiegeleisen," an iron compound containing a large percentage of carbon. The molten steel is cast into moulds and rolled. Steel rails are largely manufactured in this way.

Properties. Steel is a malleable metal, can be forged and welded, and will stand shocks. It can be tempered and can be melted. Good steel is flexible, has a fine texture and is a durable material. The higher the percentage of carbon the greater is the ultimate strength of steel and the lower the percentage elongation. The carbon contents also affects the temper and the welding qualities of steel. A high carbon steel takes a good temper and is hardly weldable, while a low carbon steel takes no temper but welds readily.

The following table shows a comparison between several of the properties of the various grades of steel in common use and their carbon content:

Grade	Per cent. Carbon.	Tensile Strength pounds per sq. in.
High Carbon Steel	1.0 to 0.3	70000 to 80000
Medium Steel	0.4 to 0.2	60000 to 70000
Low Carbon Steel	0.3 to 0.05	50000 to 60000
Grade	**Temper.**	**Welding.**
High Carbon Steel	Takes good temper	Welds difficultly
Medium Steel	Takes poor temper	Weldable
Low Carbon Steel	Takes no temper	Easily weldable

High carbon steel is used in making tools and machinery. Rails and beams are generally rolled from medium steel, while the softer grades are used in making plates and rivets.

In addition to carbon, steel contains a certain amount of impurities, like manganese, phosphorus, silicon, sulphur, etc.

Manganese. A small amount of manganese is beneficial, as it partly counteracts the bad effects of sulphur and tends to prevent hot shortness. In addition, manganese in small quantity increases malleability, elongation, toughness and tensile strength. An excess of manganese is undesirable, as it tends to make the steel cold short.

Phosphorus. This is the worst impurity that steel could contain. Even a small amount makes the steel hard and easy to break, reduces elongation and causes cold shortness.

Silicon. A very small amount of silicon makes the steel solidify on cooling without agitation, thus preventing air holes. In addition, silicon increases the hardness and the tensile strength. Steel containing more than one-half of one per cent. of silicon is brittle and unforgeable.

Sulphur. Even one-tenth of one per cent. makes the steel "red short," that is, the steel becomes brittle under the hammer or roller when hot. A small amount of manganese will partly counteract the injurious effects of sulphur.

Fracture of Steel. Low carbon steel and thoroughly annealed higher grades show a fine and silky fracture, with an angular and irregular outline, provided the breakage is produced gradually. In other cases the fracture is partly granular and partly silky, or wholly granular. In cases of sudden rupture the fracture is generally cup-shaped, with an even surface, at right angles to the length of the piece, and with a granular texture.

The color of good steel is light pearl gray.

The fracture of poor steel is dull, sandy looking and without metallic lustre. The color may be yellowish. Burned steel has a granular fracture and a whitish hue.

Nickel steel is an alloy of steel containing about three per cent. of nickel. This makes the alloy very strong. Some bars have shown an ultimate tensile strength of over 250,000 pounds per square inch, and an elastic limit of over 100,000 pounds per square inch. Nickel steel is sometimes used in bridge work. It gives a higher strength than steel per pound of metal and it materially reduces the dead weight of the structure.

Cast steel is produced from "scrap" steel made by any process, or from pig iron melted together with a certain amount of spiegeleisen, manganese, etc. The mixture is heated to about 1500° C. and then poured. Cast steel is hard and strong, but brittle when raised above a red heat. Small amounts of manganese and silicon reduce the size and number of blowholes, but render the castings more brittle.

Steel castings contain generally from 0.25 to 0.50 per cent. of carbon and have an ultimate tensile strength from 60,000 to 100,000 pounds per square inch.

Cast steel is extensively used for axle-boxes, cross-heads, base plates for machinery, and in some cases in building work for cast steel shoes or bases in place of cast iron bases.

Common Defects in Steel. Blow holes or air holes are defects caused by confined air or by the escape of gases evolved during cooling. In steel ingots they occur generally near the outer surface of the same and toward the upper part of the ingot.

Pipes are cavities caused by the outside of the ingot cooling more rapidly than the inside. This defect usually occurs within conical lines in the upper third of the ingot, and is discovered in an ingot by cutting off the metal near the upper part. If an ingot having pipes is rolled into shapes, the defect will show in the surface of the rolled material as a line of cavities.

Burning occurs when a piece of steel is overheated. It is indicated by small cup-like holes called "pits." If a burning piece of steel is withdrawn from the fire it will throw off an abundance of sparks.

Cinder spots result from fragments of fire brick, dirt or cinders which have been rolled into the metal.

Cracks are due to rolled out blow holes. These cracks, although small in the beginning, may be the starting points for ultimate rupture. Steel with cracks should be rejected.

Laps result from careless rolling or hammering. A portion of the steel is folded over itself, while at the same time the walls are sufficiently oxidized to prevent the parts from

uniting. Laps or laminations run parallel with the length of the piece and continue for a considerable length. Laps can be easily noticed on the surface of the metal.

Seams are open and elongated blow holes which have been brought to the surface during rolling, without being closed by the rolling process. They are usually not continuous and only one to two inches long.

Snakes consist of small lines twisting in all directions, and are due to foreign substances separating two masses of pure steel.

Stars are bright spots in mid-section, which are formed when the pipe in the ingot is not completely cut away before rolling.

Cobbles are irregularities which result when one side has been heated more than the other.

Advantages. Good steel is a durable material. The low carbon varieties can be readily welded, and are fast replacing wrought iron in the manufacture of a large variety of ornamental work. Steel is slightly stronger in compression than in tension, and is malleable and ductile.

Steel wires can be made sufficiently small in diameter to be burned in the flame of an ordinary match. In general, the smaller the diameter the higher the ultimate tensile strength. Steel wire can be manufactured to stand 150 tons per square inch in tension. It is therefore used for cables in suspension bridges. Steel is more homogenous and more reliable than either wrought or cast iron. It also has greater strength and stiffness than wrought iron, and since the price of steel is about the same as that of wrought iron, steel has practically replaced wrought iron for structural purposes. A considerable amount of steel is used for railroad rails and for bridges and buildings.

INSPECTION OF STEEL.

Testing. Following are the tests generally employed to determine the quality and other properties of steel:

1. Tensile tests are made to determine the tenacity and ductility of the metal. The tenacity is indicated by the elastic limit and the ultimate strength of the specimen. The ductility is measured by the per cent. elongation between two points marked with a pointer on the test piece before testing, and from the decrease or per cent. reduction of the cross section of the test piece.

The common shape used for sheared plates is shown in Fig. 8. The middle portion is 1½ inches wide and of the same thickness as the original plate. Points are marked

every inch on the central portion with a steel pointer. The distance between two points, one on each side of the fracture and 8 inches apart, is measured after the test, and the per cent. elongation in 8 inches is thus determined by carefully measuring the dimensions of the cross-section at the point of rupture before and after the test. The reduced area is computed, and from this the per cent. reduction.

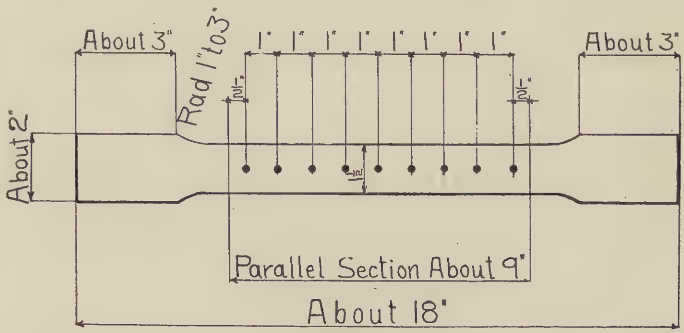


Fig. 8—Test Piece.

For shapes other than plates, similar test pieces are used, after same have been planed or turned parallel throughout their entire length. The elongation is measured in 8 inches of the original length.

Rivet rounds and small bars are tested of full size as rolled.

2. Cold bending. Rivet or soft steel shall bend cold 180 degrees, and close flat upon itself without showing any cracks. For plates flat pieces one inch wide and of the original thickness may be used.

3. Hot bending. A piece of medium steel is heated to a cherry red, then cooled in water at 70° F. It is then bent 180° around a rod whose diameter equals the thickness of the test piece. No cracks should result.

4. Drifting test. Drive a drift pin through a punched hole in a plate, using a sledge hammer. Notice how much the hole can be enlarged without fracturing the metal. A hole for a ¾ inch rivet in a steel plate, and with the center of the hole not nearer to the edge of the plate than 1½ inches, shall be capable of passing a drift pin 1¼ inches diameter without fracture.

5. Hardening test. The specimen is heated to a red heat, then plunged in water at freezing point. Then bend the bar, and compare the results with those obtained from

similar pieces not hardened. The effect of hardening is thus ascertained.

6. Forging tests. This is used for rivet rods. One end of the rod is heated to a red heat, then flattened with a hammer. If any small cracks appear this indicates red shortness.

7. Welding test. A bar one square inch in cross-section is heated to a white heat, then upset and drawn down to the original thickness with a ten-pound hammer. Neither flux nor water should be used. The bar is then tested in tension.

8. Quenching test. Heat the steel bar to a cherry red and plunge in water at 80° F. Then bend the bar around the curve 1½ times its diameter. No cracks should appear on the outer part of the bar.

CHAPTER IV.

Shop and Mill Inspection of Iron and Steel.

Shop Operations. Following are the main operations to which iron and steel are subjected in a structural shop and to which the shop inspector should pay considerable attention: Straightening, marking off and punching, second straightening, reaming, assembling, second reaming, riveting, facing, boring, finishing, fitting up, oiling, painting and shipping.

The shop inspector must be provided with a set of working drawings, a bill of materials and a copy of the specifications.

He must also see that all material is straight before and after punching; otherwise the riveting will be deficient, with loose rivets caused by the spring of the bent parts. The inspector should also examine the punch dies occasionally to see that the edges are sharp and unbroken and that the difference in diameters between the upper and lower dies does not exceed 1/16 in.

The shop inspector must examine all dimensions of finished parts, must see that all rivets and bolt holes are in their proper places and must make sure that all field connections match. He must see that all errors are corrected at the shop.

Connections to be riveted in the field may be checked by assembling the parts in the shop, or by reaming both parts in succession to the same template.

Drifting should be used only for bringing pieces together preparatory to riveting. After part of the rivets are in place, drifting may injure plates and rivets by causing distortion. Pieces should be kept together preparatory to riveting by means of a sufficient number of temporary bolts. The inspector should also see that parts inaccessible after riveting are painted at least one coat of paint, and that all stiffeners fit tight and good.

After riveting each rivet is tested to see that it is tightly driven and that the head is properly formed.

In boring and facing the inspector must see that all pin holes are of the proper size and at the proper distance centre to centre. He must also see that the ends of pieces are properly planed to the required bevels and that the lengths of milled end pieces are correct.

The shop inspector marks for identification all the pieces approved by him. This is done by causing some mark or initial to be impressed on all parts approved by means of a special inspector's hammer. A circle of red paint around the mark will make it easily to locate.

ADDITIONAL SHOP AND FIELD OPERATIONS AND THEIR EFFECT UPON IRON AND STEEL.

Heating. Cast iron of average quality is slightly affected by heat below 900° F. At a red heat it looses only one third of its strength. Wrought iron and steel loose no sensible portion of their ultimate strength up to about 500° F., but beyond this point the strength decreases rapidly with the increase in temperature. At 800° F., both steel and wrought iron may lose one-fifth of their ultimate strength.

Welding consists in joining together two pieces of metal with the aid of heat and that of hammering, and with or without the use of a flux. Wrough iron is the easiest iron to weld at a white heat. Steel is less weldable than wrought iron and it becomes less and less capable of welding, the higher its carbon content. Cast iron is not weldable. Welding weakens the cross-section of a bar at the point of weld, and for this reason it is often specified that no welding shall be allowed in any steel that is used in main steel structures. A welded bar of steel or wrought iron may have in the weld as little as 60% of the strength of the original solid bar.

Forging consists in raising a metal to a high temperature and hammering it into any desired form. The metal must not be overheated or burned. Overheating lowers both the tensile strength and the ductility. Steel is more affected by overheating and therefore requires more care than wrought iron. Either metal, however, when heated fully, should be quickly worked, as working at a cool stage is injurious.

Steel or iron worked at a blue heat, or at about 600° F. becomes "blue short" or brittle, being too cold to be hammered. A simple way to tell when a bar or plate is too cold to be hammered, is to press against the metal a piece of wood or the end of the handle of the hammer. If the mark thus made on the metal will not glow, the piece must be reheated.

Hardening consists in heating the metal to a red heat and then in cooling it rapidly, by plunging into oil, water, brine or molten lead. The quicker the heat is extracted the harder will the metal be. Oil extracts the heat slower than water; water extracts the heat slower than brine. Hardening increases the ultimate strength as shown by tests if the load

is slowly applied. Hardening also increases brittleness. In order to make the metal tough enough for use after hardening, it has to be subjected to the operation of "tempering." Steel with 40% carbon can be hardened sufficiently to cut soft iron and maintain an edge.

Tempering consists in reheating a hardened piece of metal to a certain point and then allowing it to cool by plunging it into water. When a hardened steel bar is reheated, the hardness decreases as the heat increases. In the same time various colors due to oxides appear on the surface of the steel with increasing temperature and by means of these colors, the heating may be stopped at any desired point and the corresponding hardening can thus be obtained.

Beginning with the cold metal, the tempers of different colors are sometimes described as follows:

Light straw Straw	Used for files, lathe-tools, etc.
Light brown Darker brown	Used for drills, reamers, taps, etc.
Brownish blue or pigeon wing	Used for axes, hatchets and tools.
Light blue Dark blue	Used for springs.

Both tempering and hardening cause an increase in the elastic limit and ultimate resistance, and a decrease in ductility. Both processes are generally used in making steel wire and tools, but very seldom in structural work.

Annealing consists in heating a metal object throughout to a high and uniform temperature, and then allowing it to cool uniformly in the air.

For annealing purposes the steel is generally heated above 1000° F. It is then allowed to cool in the air or under a muffle, or it is kept in the heating furnace, but the temperature of the same is gradually reduced. This last method gives as slow a cooling process as may be desired.

The object of annealing is to make the metal uniform in density throughout. When a piece of iron is hammered, bent, or upset, the uniform density of the metal is considerably changed at various points and internal stresses are the result. Annealing causes the various minute particles of metal to readjust themselves, thus reducing and perhaps totally excluding internal stresses.

All pieces that have been hammered, bent or upset, should be annealed.

Punching and Shearing. In both these operations the metal is subject to shearing forces, and therefore the effects are practically the same. Punching and shearing in iron and steel cause an increase in the elastic limit with lower ductility and lower ultimate strength; consequently both processes injure the strength of the metal.

In punching and shearing minute cracks are started at the edges of the metal. These cracks are injurious as they may extend within a short time and become dangerous before being discovered. They also reduce the ultimate strength. In the same time the disturbance caused by shearing hardens the sheared edges and this explains the loss of ductility and the increase in elastic limit.

It is evident from the nature of the shearing process, that thinner plates will be less injured than heavier plates. Also, if punches, dies and shears are maintained in a sharp condition the metal will be more cleanly cut and there will be less cracks started.

The injurious effects caused by punching and shearing can be removed by annealing, reaming or drilling. For reaming and drilling, the rivet holes are punched ⅛ in. smaller in diameter than the finished holes; then by means of a cutting tool or a drill 1/16 in. is removed all around the hole. In case of sheared plates remove 1/16 in. all along the sheared edges. Reaming removes almost entirely the injurious effects caused by punching or shearing and in this respect is superious to annealing.

Wrought iron and soft steel are less affected by punching and shearing than the higher carbon steel.

Upsetting is the operation of thickening an iron bar by hammering back against its end. Upsetting is used in making eye bar heads. The end of the bar is hammered, then flattened, and finally a pin hole is drilled through. In riveting the shank or body of the rivet is upset to fill the hole completely and then to form the new head from the remaining metal. In all cases of upsetting the metal to be upset must be heated and worked at a temperature high enough to cause a flow without bending or folding. With proper care upsetting gives satisfactory results.

Caulking. When two pieces of metal are riveted together, the operation of hammering down the edges of one of the pieces in such a manner as to make them slightly penetrate into the other piece is called caulking. (Fig. 9).

Caulking is an approved process in boiler and tank work and is applied to both rivets and plates, in order to secure water tight joints. For this purpose a narrow, blunt chisel-like

tool called a caulking tool is used. This tool is about 3/16 in. thick at the end and 1½ in. wide, with the edge ground to an angle of 80°. In case of boiler plates these are usually planed on edge to a bevel of about 75° to 80° to facilitate the forcing down of the edge. As shown in the diagram the effect of caulking is to burr down the plate at the joint, forming a metal to metal joint, care being taken not to damage the plate below the tool, or spring the joint open. Usually both

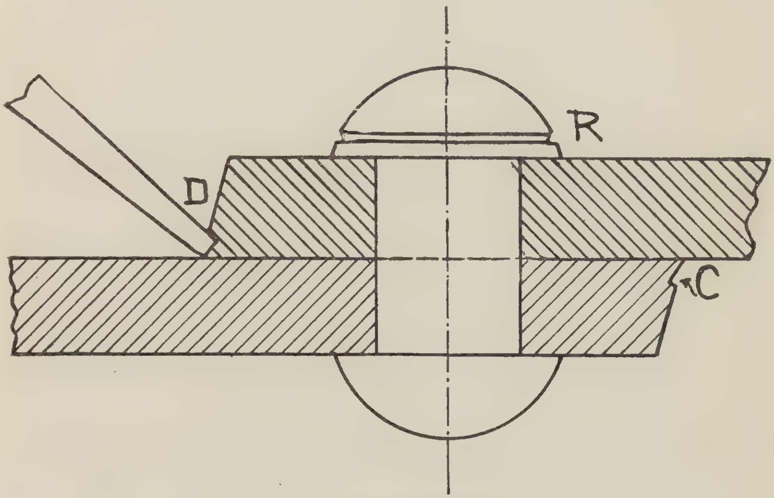


Fig. 9—Caulking.

edges C and D are caulked, and the rivet heads also, if they leak as at R. Caulking has no legitimate use in structural work. It is used to make loose rivets appear tight, instead of cutting out and replacing such rivets. It is also used when the edges of the rivet head are not quite close to the plates, or when an opening exists between the plates themselves. The edge of the rivet head is usually hammered down until it indents and slightly penetrates the surface of the plate. This makes a loose rivet appear tight when tested with a hammer. Close inspection should detect and condemn such rivets.

CHAPTER. V.

Riveting.

A Rivet is a pin of metal consisting of a "head" and a "shank" or cylindrical body which is driven through two or more pieces of metal, and then the point is bent or spread and beat down fast, to prevent its being drawn out.

Material. Rivets are usually made of soft steel or wrought iron. Copper rivets are sometimes used where iron would corrode too quickly. The steel used for rivets will generally have an ultimate tensile strength between 52,000 and 60,000 lbs. per sq. in. In such steel the carbon may run down to .06 per cent. with the sulphur between .02 and .03 per cent. and phosphorus even lower. Rivet steel must be ductile and tough and must stand well the effects of variations in temperature. Wrought iron rivets are less affected by temperature than steel rivets. In driving field rivets or in riveting done after the parts to be riveted are in place, the usual method is to heat the rivets in a portable forge resting upon a temporary platform made of planks, and then each rivet is thrown through the air to the riveters at the various points where riveting is being done. While the rivet is thrown through the air it partly cools off. Steel rivets may thus cool down to a point where good riveting can no longer be obtained, while if the steel rivet is heated in the forge to a slightly higher temperature and then thrown through the air, the rivet is often injured and the steel composing it is red short or liable to crack at a red heat. Wrought iron is less liable to injury from overheating and is less affected by the drop in temperature immediately after leaving the forge. For these reasons wrought iron rivets are preferable to steel rivets for field riveting.

Manufacture. Rivets are made either by hand or by machinery. They are indicated by means of their length and diameter. The length of a rivet is the length of its shank when cold, and does not include the head. The size most commonly used is ¾ in. diam. rivet. In order to allow the hot rivet to enter holes easily the holes are punched 13/16 in. diam. for a ¾ in. rivet and in general 1/16 in. larger than the diameter of the cold rivet.

The hot rivet should not drop into the hole. It should require slight pressure to put it in. The diameter of the rivet holes must not be less than the thickness of the plate, other-

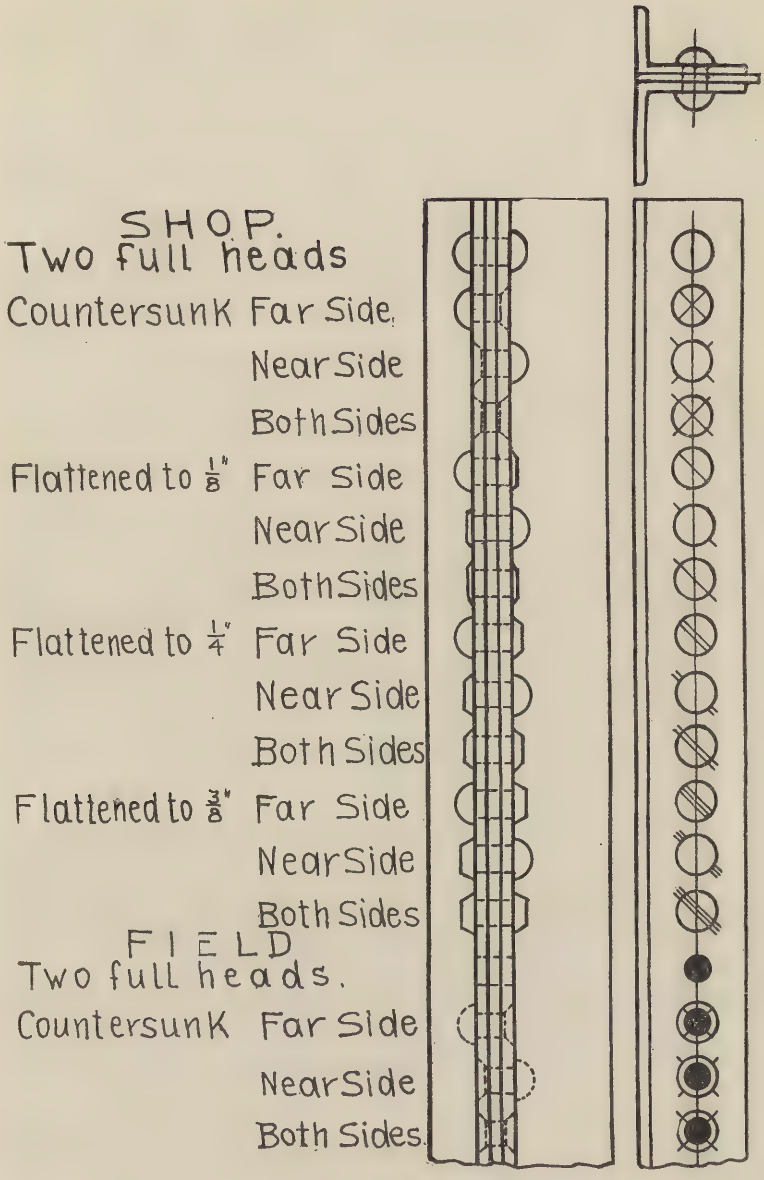


Fig 10—Rivet Signs.

wise the punch in the shop is liable to crush. For plates less than ⅝ in. ¾ in. rivets are commonly used; for plates ⅝ in. and over, either ¾ in. or ⅞ in. rivets are used.

The length of the rivet depends on the grip or total thickness of the parts joined by the rivet, and on the number of pieces to be joined by the same rivets. A hot rivet has a tendency to fill up any slight openings between the plates through which it passes. Hence to find the length of the cold rivet add to the grip about 1/32 in. for each opening between plates; then add about 1⅝ times the diameter of the rivet for the new head and about 8% for filling up the hole which is slightly larger than the rivet. For instance, to join two ¾ in. plates with ¾ in. rivets we need for:

	Inches.
Grip	1½
Opening between plates	1/32
New rivet head, 1⅝x¾	1 7/32
	2¾

to this add about 8% or 7/32 in. and this gives in all about 3 in. as the required length of shank for the cold rivet. The same value could be obtained from a table at the end of the volume which gives the length of rivet shanks to the nearest ⅛ of an inch. For countersunk rivets add only one half the diameter of the rivet for the new head. No rivets should be used which are too short; such rivets do not leave sufficient material for the new head and the usual result is loose rivets. Rivets that are too long require additional hammering and are hard to make tight.

Form of Rivets. There are in use several forms of rivets. These forms are generally indicated on drawings by the conventional signs shown in Fig. 10.

The diameter of a head of a rivet, when such head is finished with a tool called a "snap," should be about one and a half to twice the diameter of the shank.

The height of the head of a snap finished rivet should be about three-fifths the diameter of the shank.

Fitting Connections. Before riveting the two or more parts which are joined by this process have to be brought close together and in such a relative position that the corresponding rivet holes should match as nearly perfect as possible. In connections taking in a large number of rivets, like column splices or large gusset plates, the various pieces are made to match by hammering the buckled or bent parts with a sledge hammer and then by placing temporary bolts through about thirty per cent. of the rivet holes. When

these bolts are made tight, all the holes in the connection will match, if the shop punching was carefully done. With careless punching some of the holes may not fall fair anywhere from 1/32 in. to ¼ in. and more. In such cases the holes are made fair by reaming, using either hand reaming or machine reaming. Where the rivet grip is to be two or more inches machine reaming is essential.

It is a common practice in building work where holes do not match by 1/16 in. or a little more, to drive a drift pin through the holes and make them match.

A drift pin is a round piece of steel made slightly tapering, and should be used only for easily bringing pieces together preparatory to riveting. The drift pin may also be used in correcting burrs and in smoothing out holes. It should not be used, however, to enlarge a hole. Forcing a drift pin through a hole injures the metal, causing a hardening of the material around the hole, with a corresponding increase in the elastic limit and a decrease in ductility. This is considered injurious, and good specifications prohibit the use of drift pins for enlarging holes. Instead of this, reaming should be used whenever possible. For this purpose compressed air reamers are employed on many good structures. The action of these reamers is similar to that of a drill of large diameter, and the holes are made perfectly smooth. In some cases it will be found that one or more holes have been omitted by mistake in some of the parts to be riveted. This can be remedied only by drilling through the blind hole. It also may happen that the men in the shop have punched more holes than required. In good work any hole which is not to be filled in by a rivet or bolt is plugged up with lead. This prevents corrosion to a certain extent; it also fills up the cross section, which is desirable in compression members.

Riveters. The work of fitting up connections is partly done by "fitters" and partly by the riveting gang. A riveting gang consists usually of four men, i. e., heater, passer, holder up, and riveter. Such a gang will drive about 250 rivets in a day of eight hours. Each man gets about five dollars a day, and adding to this the cost of supervision and of the materials, together with the depreciation of tools, etc., the cost of field rivets will not be far from ten cents apiece. Where two or more riveting gangs are employed there is usually a boss riveter and fitter, at about six dollars a day, who is responsible to his superintendent for the work done by the riveting gangs and fitters.

Tools and Instruments Used in Riveting. Following are the essential parts of a riveting outfit:

The forge for heating rivets.

A dolly bar for backing up the old rivet head while the new one is being formed. The dolly is a round iron bar, with one end hollowed out, or cup-shaped, in such a manner as to fit the rivet head. A dolly bar weighs from 15 to 25 pounds.

The snap is a hollowed out or cup-shaped hammer used for forging the heads.

The forging hammer is used in hand riveting for upsetting the shank or the red hot rivet and for roughly shaping a new head. Forging hammers usually weigh about five pounds each.

In hand riveting, after the new head has been shaped roughly with the hammer, one of the men, usually the rivet "passer," holds a snap against the rough rivet head while the riveter strikes a few good blows on this snap. This gives the rivet head a spherical form.

A portable air compressor, popularly known as a "gun," is used for riveting in work where machine riveting is required. The shape of the driving hammer is similar to that of the snap. Hence no extra snap is used in machine riveting, the rivet head being formed and made spherical in one operation.

The buster is a blunt-faced hammer having a cutting edge used in shearing off the heads of rivets.

After the head of a defective rivet has been cut off, the balance of the rivet is driven out from the hole by means of a special hammer having a tapering head. This hammer is known as the backing-out punch.

Drift pin is a round piece of steel, slightly tapered, and used for the purpose of drawing pieces together so as to make the holes match preparatory to riveting. Each riveting gang is provided with several drift pins.

A ten-pound sledge hammer is used in straightening out all lugs and splice plates which have been buckled or distorted during shipping or during erection.

The sledge hammer is further used in connection with backing out punches, busters, etc. It is also used with snaps to form cup-shaped rivet heads, and for this reason it is sometimes referred to as the cupping hammer.

The ratchet is a portable hand drill used for making holes on the job where same have been omitted.

The steamboat ratchet is a turn-buckle device to which cables are attached. It is used for bringing up or pulling columns into a plumb position.

We may add to this list bolts, rivets, washers, fillers, and other minor parts. Each gang is further provided with

several planks for a temporary scaffold and with ropes or chains for fastening their scaffold to the steel work.

Heating Rivets. Good riveting depends to a considerable extent upon the care used in heating. Rivets carelessly heated may burn; this greatly reduces the strength of the rivet. In addition, after the rivet is driven there is no way of telling whether the rivet was burnt or not, as the head may look good while the shank is weak and brittle.

Steel rivets should be heated uniformly to a dull red; the orange color must not be passed. The rivets should be put in place as soon as they reach this temperature and should be worked as quickly as possible. No steel rivet should be worked at a blue heat.

With machine driven rivets the point of the rivet is often heated more than the head. This facilitates the upsetting and flowing of the rivet metal into the hole. When the riveting is done by hand the pressure made to bear upon the rivet through successive blows is considerably smaller. Hence the rivet should be heated uniformly, or the head should be even hotter than the point, otherwise the blows which will upset the rivet and make it fill the hole near the point will have little effect at the other end, and the rivet may not quite fill the hole near the original head.

Iron rivets can be heated without serious injury even to a "wash" or "waste" heat, which is reached when the slag in the metal begins to soak out. Like steel rivets, iron rivets should not be worked at a blue heat.

The following additional rules if followed will contribute towards good riveting:

1. The forge used for heating the rivets should be placed as near to the point of use as practicable.

2. Only a few rivets should be placed in the fire at a time, otherwise some are liable to be left in too long and be burnt.

3. When the rivets are too long it sometimes happens that the heater will burn the points on purpose, just to shorten the shank. This is bad practice and should never be allowed.

4. Re-driving cold rivets injures the heads and should be prohibited.

5. Caulking of rivet heads may injure both the rivet and the plate, and has no excuse in structural work. It is used to make loose rivets appear tight, and should not be permitted. All caulked rivets should be cut out and replaced.

6. Rivets should not be heated several times, nor should they be allowed to remain too long in the forge. In both cases a chemical action of decarbonization and oxidation takes place, and this may injure the rivet when prolonged.

Riveting may be defined as the process of passing a hot rivet through holes in pieces to be united and of forging another head from the projecting shank. It is generally performed by means of air, steam or water power machines, or by hand.

Hand Riveting. In this kind of work the red hot rivet is passed through the hole; it is then held up in place by means of the iron bar called "dolly." This bar is hollowed out at one end in the form of a cup that fits on the rivet head. The dolly is pressed against the rivet head by one of the men, the "holder up," and in the same time the shank is upset by the riveter, who uses a forging hammer with a flat face. The end of the rivet is roughly hammered to a convex point. It is then finished or rounded up, just as the rivet loses its red heat, by placing a "snap," or hollowed steel tool, against the rivet head, and by striking a few blows with a heavy sledge hammer.

Machine riveting is performed by pneumatic, steam or hydraulic riveting machines. It is better and generally cheaper than hand riveting. The practically steady pressure brought by the machine upon the rivet enlarges the shank and squeezes it into the hole, thus thoroughly filling up all the irregularities of the hole, in addition to forming the new head.

Machine driven rivets can be easily distinguished from hand driven rivets. In the first case the rivet head is smooth and more regular, with exception of a slight burr which is often found on the new head and which is due to the die having caught the rivet a little off the centre. Furthermore, machine driven rivets will generally fill up all the irregularities of the hole; when such rivets have to be cut out, after chipping off one head, the balance of the rivet can be pushed out only by means of a pin and hammer, and with great difficulty, while in some instances the rivet will have to be drilled out.

In hand riveting when one head is cut off the shank can be driven out easily, or it will actually drop out. This shows how little hand riveting fills up the irregularities of the hole as compared to machine work. Hand driven rivets also have their heads covered with marks made by the hammer and by the shifting of the snap during forging.

In comparing machine with hand riveting, we may note the following points to the advantage of machine work:

1. In machine riveting the holes are better filled.

2. The rivet is more quickly headed, due to a larger pressure, hence there are, as a rule, less loose rivets than with hand riveting.

3. The work is more uniform and more reliable.

4. Machine riveting is generally cheaper.

Shop and Field Rivets. Hand riveting done in the shop is generally stronger and better than field riveting done in the same manner. With machine riveting and good supervision there is little difference if any between shop and field work. Some specifications require ten per cent. more field rivets than shop rivets for the same connection, when driven by machine in the field, and twenty-five per cent. more when driven by hand. Machine rivets are more uniform in strength than hand driven rivets.

There are several causes which tend to make shop riveting better than field work:

1. Parts to be riveted together can be handled more conveniently in the shop.

2. The heating of the rivets is done under more favorable conditions and close to the riveting machine.

3. Powerful stationary riveting machines are sometimes used. These are definite in their action and results and will generally turn out better work than the portable field riveting machines.

4. The conditions of inspecting the work in the shop are more favorable. This results in better inspection.

5. The stock of rivets kept in the shop is, as a rule, considerably larger than that kept on the job. This avoids the use of short rivets when the rivets of proper length do not arrive on time, as it sometimes happens in field work.

The New York Building Code allows for steel rivets in shear a unit stress of 10,000 pounds per square inch for shop rivets, and only 8,000 pounds per square inch for field rivets. This gives for a ¾-inch shop rivet 4418 pounds shearing resistance, while the corresponding value for field work would only be 3534 pounds. With good field riveting, however, 4000 pounds per ¾-inch rivet in shear may be safely assumed.

Rivets vs. Bolts. Good riveting is better than bolting for the following reasons:

1. The rivet is forced into the hole and fills it completely. This adds strength in the case of compression members.

2. Riveting furnishes a more rigid connection than bolting. For this consideration riveting is generally used in column splices.

3. The rivet heads upon cooling draw the riveted parts more firmly together.

4. Each rivet filling its hole, moisture cannot work its way into the joint; thus deterioration through rust around a rivet is prevented or delayed.

5. Stresses are likely to be more evenly distributed among a number of rivets than among the same number of bolts. To illustrate this, consider a hanger A (Fig. 11) connected to the web of a channel B by means of two ¾-inch

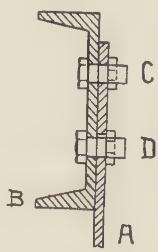


Fig. 11—Bolted Hanger.

bolts. The bolt C was first put in. The second bolt hole in the plate was punched 1/16 of an inch too high. The lower hole was elongated and the bolt D was put in, but as shown in the diagram this bolt takes no load in shear and hence the upper bolt may be overloaded. The only use of bolt D is to slightly prevent the downward motion of the hanger through the friction caused by making this bolt tight. By using rivets, although the lower holes do not match, the upset shanks will completely fill the hole spaces, and both rivets will share more evenly in resisting the shear due to the load supported by the hanger.

It often happens that splices in columns along the walls cannot be conveniently riveted on account of lack of room. In such cases the adjoining wall may sometimes be broken off for one or two feet next to the column splice, thus making riveting possible. Where the adjoining walls are weak, and where breaking into them may render such walls unsafe, as many of the holes as are not accessible for riveting

are either provided with ¾-inch bolts or else such holes are "plugged up" by driving through them red hot rivets and then upsetting the shank by means of a small hand hammer, or by using one end of a dolly bar. Where bolts are used they should be made tight, and then the thread of each bolt should be checked or distorted in order to prevent the loosening of the bolt. From what was stated before, it is obvious that rivets in plugged up holes, although not good looking and with a non-snapped head, are often preferable to ¾-inch bolts in 13/16-inch holes.

Specifications. Riveting is more expensive than bolting, but riveted joints lend to a steel structure the rigidity which is essential to the safety and durability of the finished building. Where rigidity is lacking, the ceilings may crack, the walls may open, and the whole structure may become unsafe and useless in a comparatively short time. The attention paid to rigidity depends mainly upon the purpose and the proportions of the structure. A very narrow and tall building will have to have strong, rigid joints to resist the effect of wind pressure. A structure used for manufacturing purposes where heavy machinery is employed requires rigid connections to resist the effect of accumulated vibrations due to repeated pounding of such machinery.

For buildings used for printing presses or similar heavy machinery the specifications usually require all connections to be riveted.

In loft and office buildings it is customary to have all column splices and all connections of beams to columns or beams to beams within 3′-0″ from a column, riveted; all other connections bolted. There is nothing in the New York Building Code that requires riveted field connections in structural work, with the exception of a minor restriction shown in the difference between the allowable working stresses for field rivets and field bolts. The Building Code allows, i. e., in shear:

For field rivets, 8000 pounds per square inch, which amounts to 3534 pounds for a ¾-inch rivet.

For field bolts, 7000 pounds per square inch, which amounts to 3372 pounds for a ¾-inch bolt.

The rivets and bolts being steel.

This shows that about 14 per cent. more field bolts than field rivets are required in a connection to comply with the law. In the case of a twelve-story loft building where this condition was fulfilled with regard to column splices, and where the iron erector was given the choice between bolting and riveting at the same price, he chose bolting. Bolting

column splices in anything like a twelve-story loft is considered poor practice and should not be encouraged.

Faking Riveting Work. Poor field riveting may naturally be expected from men who just start into this kind of work and who have little experience in overcoming difficulties and new conditions which constantly arise before them. Most of the defective work, however, is due to carelessness, lack of active supervision and unreasonable speed, caused by a desire of some gang to turn out more work than other gangs in the same time, or by the compelling action of some foremen or superintendents, who will discharge a gang doing first rate work when the number of rivets driven in a given time falls below their expectation. Poor work is sometimes due to defective tools, to holes not matching correctly, to driving rivets through such holes without reaming, and to using rivets of improper lengths. Defective work may also be caused through careless heating, slow and careless driving, improper backing up and so on.

Most of these faults are manifested in the finished rivets, either through unsatisfactory size and shape of the new rivet head or through the loose condition of the rivet.

Faking generally consists in making a loose rivet appear tight under a hammer test. Here are some of the common ways:

1. By going around the head of the rivet with a caulking tool. This will make the rivet sound all right, and the mark due to caulking will generally not be noticed unless carefully looked for.

2. By driving over the cold rivet heads, using a smaller snap.

3. By hammering or in any way deforming the original heads of the cold rivets. There is absolutely no reason for such action, and any such rivets should be regarded with suspicion.

4. By placing the snap sideways upon the rivet and striking it a few good blows with a sledge hammer. The snap is usually applied below the head, where it cuts a ridge in the plate and makes the rivet appear tight by forcing part of the plate metal under the head.

A similar action takes place in machine riveting when, after driving all rivets in a given splice, the riveter goes over loose rivets with his riveting machine and re-drives the cold rivet heads. This usually results into forming a groove or circle all around the rivet head. In few cases such a groove or a snap mark as above described may be formed in driving

a perfectly tight rivet, and due judgment is necessary in condemning defective rivets.

It is a good policy to dismiss any gang of riveters which persistently continues to do poor work.

Testing Rivets. Complete rivet testing involves a test of the rivet metal for tensile strength, bending and ductility. In addition, the riveting inspector must observe the following points:

1. The rivet holes must match correctly.

2. All rivets must be heated properly.

3. Each rivet must be of sufficient length to fill the hole completely.

4. The edges of the rivet heads must be free from caulking marks.

5. The plate metal around the head should be free from any ridge or impress.

6. Both rivet heads should fit tight against the plates.

7. The rivet heads should be free from cracks.

8. The rivet heads should be concentric.

9. The rivet heads should be of full size.

Loose rivets are easily detected by means of one or two blows struck with a one-pound hammer upon the rivet head. In case of rivets driven horizontally in a column splice, for instance, strike one blow downward against the head of the rivet at an angle of about 60 degrees to the length of the rivet; then strike a symmetrical blow upward. If the rivet is loose a jar or rattle will be produced. By holding one finger against one head while the other head is struck with the hammer even the slightest jar can be easily detected. In absence of a hammer, any piece of iron, even a cold rivet, may be used to perform this test.

Rivets are easier to examine before being painted; for this reason it is customary in good work not to paint any column splices until all rivets have been approved by the inspector.

CHAPTER VI.

Specifications.

Plans and specifications for each particular construction must be the inspectors and builders' guides for the quality of the materials used as well as for the grade of workmanship required. Specifications must be definite, concise and clear, and must not contain anything contrary to law. In most cases the specifications are separate from the plans; for small jobs, however, the entire specifications may be written on one or all of the plans. Good specifications will carefully take up all the requirements of the architect or engineer in relation to the quality of material, shop-work and erection, as well as shop and field inspection.

Following are some of the main points to be considered in drawing up specifications:

1. **QUALITY OF MATERIALS.** This includes:

(a) Finish. All material should be free from surface defects and should possess an excellent finish.

(b) Weight. Any member lacking in weight more than 2½ per cent. may be rejected.

(c) Manufacture. All steel to be made by the open hearth process; all material should be uniform; all cast iron satisfactory.

(d) Physical Properties. Rivets should be made of soft or low carbon steel. All other steel should be of the medium grade. Specify the number of test specimens required for the various physical tests, the elastic limit, the ultimate strength and the per cent. elongation. Specify how test specimens should be collected and tested.

(e) Chemical Properties. Steel having a definite chemical composition will usually have certain definite physical properties. Where the physical requirements are specified in detail, do not specify also the chemical composition. Arbitrary physical and chemical requirements can not always be obtained in the same specimens. The most that could be done is to specify that certain deleterious substances like phosphorus and sulphur should not exceed a certain percentage.

2. **SHOPWORK.** This takes in:

(a) Correct Dimensions. All members must be of cor-

rect length in accordance with plans approved by the architect.

(b) **Punching.** The diameter of the die should not exceed the diameter of the punch by more than 1/16-inch.

(c) **Straightening.** Before assembling each piece should be made straight.

(d) **Assembling.** A sufficient number of temporary bolts should be used.

(e) **Reaming.** To be performed to make all holes true before riveting.

(f) **Riveting.** To be done right, and all defective rivets to be replaced.

(g) **Painting.** All metal to be cleaned from rust before painting. Specify the paint to be used.

3. **ERECTION.** This should cover:

(a) **Safety.** All accident liabilities to be taken by the builder.

(b) **Bracing.** All necessary temporary bracing and guying to be provided.

(c) **Connections.** All connections, whether riveted or bolted, to be in accordance with the plans and specifications.

(d) **Overloading.** Floors or other parts of the structure should at no time be overloaded.

(e) **Painting.** All accessible parts to be properly painted with the kind of paint specified for the purpose.

(f) **Workmanship.** To be in accordance with good practice, and satisfactory to the architect.

4. **SHOP AND FIELD INSPECTION.** Here should be provided that:

(a) **All reasonable facilities** should be provided for inspectors for the performance of their duties.

(b) **Rejection.** The architect's inspector should have the authority to reject defective materials and workmanship.

(c) **Any disputes** as to the meaning of the specifications between the architect's inspector and the builder should be referred at once to the architect for final consideration.

The following specifications take up the physical and chemical properties of steel and cast iron, together with the requirements relating to finish, manufacture and variations in weight:

MANUFACTURER'S STANDARD SPECIFICATIONS.

Revised to February 6, 1903.

STRUCTURAL STEEL.

1. **Process of Manufacture.** Steel may be made by either the Open Hearth or Bessemer Process.

2. **Testing and Inspection.** All tests and inspections shall be made at the place of manufacture prior to shipment.

3. **Test Pieces.** The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material. The standard shape of the test piece for sheared plates shall be as shown by the following sketch: See Fig. 8.

On tests cut from other material the test piece may be either the same as for sheared plates, or it may be planed or turned parallel throughout its entire length, and in all cases where possible two opposite sides of the test piece shall be the rolled surfaces. The elongation shall be measured on an original length of 8 inches, except as modified in section 12, paragraph c. Rivet rounds and small bars shall be tested of full size as rolled.

Two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending; but in case either test develops flaws, or the tensile test piece breaks outside of the middle third of its gauged length, it may be discarded and another test piece substituted therefor.

4. **Annealed Test Pieces.** Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material shall be similarly treated before testing.

5. **Marking.** Every finished piece of steel shall be stamped with the blow or melt number, and steel for pins shall have the blow or melt number stamped on the ends. Rivet and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles securely wired together, with the blow or melt number on a metal tag attached.

6. **Finish.** Finished bars shall be free from injurious seams, flaws or cracks, and have a workmanlike finish.

7. **Chemical Properties.** Steel for buildings, train sheds, highway bridges and similar structures shall not contain more than 0.10% of phosphorus. Steel for railway bridges shall not contain more than 0.08% of phosphorus.

8. **Physical Properties.** Structural Steel shall be of three grades, RIVET, RAILWAY and MEDIUM.

9. **Rivet Steel.** Ultimate strength, 48,000 to 58,000 pounds per sq. inch. Elastic limit, not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1,400.000}{\text{Ultimate strength.}}$

Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

10. **Steel for Railway Bridges.** Ultimate strength, 55,000 to 65,000 pounds per sq. inch. Elastic limit, not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1,400.000}{\text{Ultimate strength.}}$

Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

11. **Medium Steel.** Ultimate strength, 60,000 to 70,000 pounds per sq. inch. Elastic limit not less than one-half the ultimate strength.

Percentage of elongation, $\frac{1,400.000}{\text{Ultimate strength.}}$

Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

12. **Modifications in Elongation for Thin and Thick Material.** For material less than 5/16 inch, and more than ¾ inch in thickness, the following modifications shall be made in the requirements for elongation:

a. For each increase of ⅛ inch in thickness above ¾ inch, a deduction of 1% shall be made from specified elongation, except that the minimum elongation shall be 20% for eye-bar material and 18% for other structural material.

b. For each decrease of 1/16 inch in thickness below 5/16 inch, a deduction of 2½ per cent. shall be made from the specified elongation.

c. In rounds of ⅝ inch or less in diameter, the elongation shall be measured in a length equal to eight times the diameter of section tested.

d. For pins made from any of the before-mentioned grades of steel, the required elongation shall be 5 per cent. less than that specified for each grade, as determined on a test piece, the center of which shall be one inch from the surface of the bar.

13. **Variation in Weight.** The variation in cross-section or weight of more than 2½ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates which will be covered by the following permissible variations:

a. Plates 12½ pounds per sq. foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent. variation above or 2½ per cent. below the theoretical weight. When 100 inches wide and over, 5% above or 5% below the theoretical weight.

b. Plates under 12½ pounds per sq. foot when ordered to weight, shall not average a greater variation than the following: Up to 75 inches wide, 2½ per cent. above or 2½ per cent. below the theoretical weight; 75 inches wide up to 100 inches wide 5% above or 3% below the theoretical weight. When 100 inches wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

c. For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order, equal in amount to that specified in the following table:

Table of Allowances for Overweight for Rectangular Plates When Ordered to Gauge.

Plates will be considered up to gauge if measuring not over 1/100 inch less than the ordered gauge. The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATES ¼ IN. AND OVER IN THICKNESS.

Thickness of Plate. In Inches.	Width of Plate			
	Up to 75 Inches. Per cent.	75 to 100 Ins. Per cent.	Over 100 to 115 ins. Per cent.	Over 115 Inches. Per cent.
¼	10	14	18	—
5/16	8	12	16	—
⅜	7	10	13	17
7/16	6	8	10	13
½	5	7	9	12
9/16	4½	6½	8½	11
⅝	4	6	8	10
over ⅝	3½	5	6½	9

PLATES UNDER 1/4 IN. IN THICKNESS.

Thickness of Plate. In Inches.	Width of Plate		
	Up to 50 Inches. Per Cent.	50 to 70 inches. Per Cent.	Over 70 inches. Per Cent.
1/8 up to 5/32	10	15	20
5/32 up to 3/16	8½	12½	17
3/16 up to 1/4	7	10	15

STRUCTURAL CAST IRON.

Except when chilled iron is specified, all castings shall be tough gray iron, free from injurious cold-shuts or blow holes, true to pattern and of a workmanlike finish. Sample pieces, one inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4 feet 8 inches, a central load of 500 pounds when tested in the rough bar.

Still another set of specifications is here given. This set is more suitable for building construction and represents the main points taken from several specifications used on actual work and forming part of the iron man's contract. The arrangement of the various sections follows closely the outline given in the beginning of this chapter.

SPECIFICATIONS FOR MANUFACTURING, FABRICATING, INSPECTION AND ERECTION OF STRUCTURAL STEEL

for the Loft Building at the S. W. Corner 18th St. and 4th Ave., N. Y. City.

John Doe, Owner.

H. Smart, Architect. V. R. Wise, Engineer.

GENERAL.

Site Examination. The iron contractor is to see the site, and to estimate for everything necessary to complete his work on the building, as shown on plans as herein specified.

Drawings and Specifications. Any iron work shown on the plans and not particularly called for in the specifications, or any iron work called for in the specifications, and not shown on the plans, must be put in the same as if it were

both shown and called for. In fact, these specifications and the accompanying drawings are intended to explain and complete each other and include everything necessary and requisite for the proper completion of the iron work in this building, notwithstanding that every item necessarily involved in the work is not particularly mentioned.

Extras and Omissions. No omissions and no additional work shall be undertaken, except upon written order signed by the architect and approved by the owner. The cost of such omission or additional work must be agreed upon before commencing same.

Work Contrary to Plans and Specifications. Any work not in accord with these specifications and the accompanying plans must be taken out and replaced at the contractor's expense by work complying in all details with these plans and specifications.

Shop Drawings. The contractor shall submit to the architect or engineer for approval, all shop drawings and details. The approval of these, however, is only as to strength and does not relieve the contractor from responsibility for his dimensions.

DIMENSIONS. The contractor must verify all figures on drawings before laying out the work; figured dimensions are to be used in preference to scale measurements; scale drawings and details in preference to small scale plans. The contractor will be held responsible for the correctness of all dimensions at the building.

Errors. Any error or omission and any discrepancy of any kind should be referred to the architect for correction as soon as discovered.

Sizes. The work covered by the contract is completely shown on the accompanying plans and these specifications; all sizes and weights of beams girders and columns are marked on the plans and the column schedule.

Changes. The contractor may, if he so desires, simplify the sizes of column sections by increasing their weight. He may replace standard beams by special beams of greater strength and weight when this will save time in delivery. He may also change splicing points indicated on the column schedule. Any of these changes, however, must not be made without the written approval of the engineer.

Official Requirements. The contractor shall comply with all State and Municipal Laws and Ordinances relating to building construction. The contractor must conform to the

Building Code whether each item is specifically mentioned and shown or not.

Damages. The contractor shall be responsible for all damages and injuries that may occur to persons, animals, vehicles or adjoining property, from whatever cause, during the progress and in connection with his work.

Personal Attention. The contractor is to give his personal attention to the work and shall have a competent foreman on the job at all times.

Tackle. The contractor shall furnish all planks, ladders, scaffolding materials and appliances necessary to complete his work to the true intent and meaning of the plans and specifications.

Bond. The contractor will be required to furnish a bond through a recognized Surety Co., or two approved bondsmen, for the amount of fifty (50%) per cent. of this contract, to guarantee the faithful performance of this agreement.

Deliveries. Shall be made in the order required for erection, and at the time specified in the contract. If deliveries are not made at the time agreed upon, the architect may purchase materials in the open mraket at such terms and for such deliveries as in his opinion shall meet the requirements of construction. The cost of such material so purchased and of its delivery to the job shall be deducted from the amount due under the contract.

QUALITY OF MATERIAL.

General. All cast iron and structural steel should be the best of its kind, both as regards quality of material and process of manufacture.

Finish. All finished material shall be straight, of correct section, and shall have smooth, clean, surfaces, free from cracks, seems, buckles or other defects.

Weight. A variation of three (3%) per cent. for cast iron and two and one a half (2½%) per cent. for steel from the estimated weights will be allowed in the finished material. Additional weight in excess of these allowances will not be paid for. Any single member or piece of material which weighs less than the estimated weight by more than the above allowance, may be condemned at the discretion of the architect.

MANUFACTURE.

Castings. All castings shall be of good foundry mixture. Only such scrap iron as may be approved by the architect or

his inspector shall be mixed with the metal used for castings. All castings shall be clean, tough gray iron, free from blow-holes, honeycombs, cold-shuts, cinders, sand, shrinking-cracks or other defects, correct as to pattern, neat as to finish and not warped. All castings shall be allowed to cool slowly in the sand to avoid shrinkage strains. Castings of incorrect dimensions and warped castings may be rejected at the discretion of the architect.

Steel. All steel shall be manufactured by the Open-hearth process, and shall be uniform in quality. Chemical analyses for each furnace heat must be made by the rolling mills and checked by the inspector. No steel shall contain more than .08 per cent. of phosphorus, nor over .06 of sulphur.

Rivet Steel shall be "soft" steel. All other steel shall be of "medium" grade complying with tests below specified.

Tests. Cast Iron. Two specimens, each 1 in. sq. shall be cast in sand molds for each furnace heat. One of these specimens shall be turned to a diameter of ¾ in. for about five inches. It shall then be broken under tension and it shall develop an ultimate tensile strength of at least 18,000 pounds per square inch. The other specimen shall be supported horizontally on two knife edges 12 inches apart. In this position the specimen shall be capable of sustaining a central concentration of 2,500 pounds, with a deflection of not less than 3/16 of an inch.

Castings shall not break when struck with a sledge hammer. A blow from a hammer upon the edge of any casting shall show an indentation without crushing or chipping off the metal.

Steel. Two specimens cut from finished materials of each furnace heat must be furnished by the rolling mill. Such specimens and all material rolled from the same melt shall be marked for indentification with the number of the original furnace melt. Each specimen shall be 1 in. wide, 18 in. long and of the same thickness as the rolled material. One specimen shall be broken in tension in a testing machine and shall show an ultimate strength of 54,000 to 64,000 lbs. per sq. in. for "medium" steel and 50,000 to 58,000 lbs. per sq. in. for "soft" steel. Its elastic limit shall not be less than 32,000 pounds per sq. inch and a minimum elongation of not less than 25% in eight inches. If the first specimen fails to develop the required strength and elongation, three other specimens may be tested at the discretion of the inspector, and if two of these specimens do not fulfill the above requirements, all material rolled from the corresponding furnace melt shall be condemned. The second specimen shall have one end heated to a

cherry red, quenched in water and bent; the other end bent cold. Both bends shall be 180° flat and shall not develop any flaws.

SHOPWORK.

General. All workmanship shall be first class in all respects and in accordance with the best shop practice.

Shop Drawings. All working shop drawings shall agree with the plans furnished by the architect and must be signed by the architect before work commences. The shop, however, must make good, without charge, any errors resulting from not following the architect's plans and errors of clearance or connections. The architect shall be furnished with not less than two sets of working plans and two sets of order lists of materials.

Dimensions. All members must be of correct length, in accordance with plans approved by the architect.

Punching. All rivet holes shall be laid out by means of a template, accurately spaced and in a true line. The diameter of the die should not exceed the diameter of the punch by more than 1/16 inch for material ½ inch thick or less, nor 3/32 inch for thicker material. All rivet holes shall be clean cut and free from cracks and burrs. Burrs shall be removed by reaming. The diameter of the finished hole shall not exceed the diameter of the rivet by more than 1/16 inch.

Straightening. All material must be straightened before and after punching.

Assembling. Before riveting, built members shall be provided with a sufficient number of bolts to prevent bending or warping during riveting.

Drifting. No drifting of holes will be allowed under any conditions. Holes that do not match shall be corrected by reaming or by new material, or by both, at the discretion of the architect.

Reaming. Shall be used to make holes match. Built-up girders shall have rivet holes punched ⅛ inch smaller, and then the holes shall be reamed to full size with the parts held in position.

Riveting. Rivets shall be of soft steel and driven by machine whenever practicable. Rivets shall be used for all column splices and for all connections within three feet from each column; other work may be bolted or riveted, at the contractor's pleasure. All rivets and bolts must be ¾ inch diameter throughout the building, except in special cases

where it is necessary to use other sizes. The pitch of rivets shall never be less than 1½ inches nor more than 6 inches, while the minimum distance from the center of any rivet to the edge of the shape shall be 1¼ inches. Rivets should not be used in tension. An excess of 25 per cent. in the number of rivets shall be allowed in all connections to be riveted in the field.

The rivets shall completely fill the holes, with full heads concentric with the holes and in full contact with the surfaces of the metal. All rivet heads shall be neat, cup-shaped, free from cracks on edges, and shall not be burned. All burned, loose or otherwise defective rivets will be condemned and will have to be removed at the expense of the contractor.

Any injury caused to the material in removing defective rivets may serve to condemn the injured parts.

Painting. Before any painting is done in the shop all scale, dust, dirt and foreign matter of any kind must be removed from the structural steel. Cast iron work shall not be painted until delivered on the job, reinspected, and approved. All covered surfaces, surfaces in contact and surfaces enclosed on all sides by riveted members must receive one good coat of paint after the pieces are punched and before they are assembled. All steel work must receive one complete coat of paint before it can be taken from the shops or exposed to the weather. All faced ends of columns and other planed surfaces must be coated with white lead and tallow before leaving the shop. After erection, all surfaces, including cast iron, shall be painted one thorough field coat. All painting shall be done on dry surfaces, and no painting shall be done in wet or freezing weather. The field coat of paint must be of a different color than the shop coat. The paint used must be one of the following:

Red lead and boiled linseed oil, mixed in proportion of 23 pounds of lead to 1 gallon of oil.

Graphite paint No. 26, manufactured by Chicago Graphite Co., or any other paint approved by the architect.

Bases. Cast iron bases must be provided for all columns where shown on plans, and must conform with approved detail drawings. All bases must be planed smooth on top and must be of the required height. The ribs must be arranged in each case so that the entire cross-section of the column shall be directly supported from the bottom of the base. The holes for the bolts connecting the columns to the bases must be drilled to a template and in exact position. Other holes and grouting holes may be cored.

Cast Iron Columns. All cast iron columns shall be of exact height, with bearing surfaces at right angles to the axis of the column. The ends shall be planed accurately and smooth. Connection-holes shall be exactly spaced and drilled to a template. The top and bottom flanges shall be reinforced by ample fillets and shall be not less than one inch in thickness when finished.

Steel columns shall be made in double story lengths except where otherwise indicated on the column schedule. Columns built of several sections shall be riveted together with ¾ inch diameter rivets spaced not more than 6 inches on centres nor more than 16 times the thickness of the thinnest plate. At splices and in the vicinity of beams and girder connections the rivets shall be spaced 3 inches for the full depth of connections. In riveting up built columns due care must be taken to keep them straight and free from twists. All columns shall be milled at each end to a smooth bearing-surface at right angles to the length of the column.

Column Splices. Unless otherwise specified by the architect, all column splices shall be made by riveting splice-plates on the sides of each column with not less than twelve rivets in each column. All splice-plates shall be ½ inch thick, except where the metal of the columns connected is less than ¾ inch thick, when the splice-plates may be ⅜ inch thick. Where the outside depth of one column is less than the other by more than 1/16 inch on each side, the clearance must be taken up with fillers of the same width and punched the same as the splice-plates. Rivet holes in columns and corresponding holes in splice-plates must match accurately. All columns will have ¾ inch cap plates. The point at which the change in section is made shall generally be two feet above the finished floors.

Beams. Any beam that is longer than required for its special place shall be rejected. Where beams connect to beams a clearance not exceeding ⅛ inch at each end will be allowed. Where beams connect to columns the clearance shall not exceed ¼ inch at each end. All beam connections, whenever possible, shall be made by means of standard connections, as shown in the Carnegie Handbook, and with the same number of rivets. Any other standard approved by the architect may be used. Wherever the details of the columns will permit, beams and girders connecting to columns shall have not less than eight rivets at each end, four in the top flange and four in the bottom flange. Unless otherwise noted, all beams and lintels are indicated to their approximate lengths and positions by single lines on the floor plans.

Beam Connections. All beams resting on walls must be securely anchored by means of approved anchors built into the wall. Under ends of all wall bearing beams steel templates shall be provided to distribute the load on the wall.

Separators. Separators must be provided for all double beams. Where double beams of the same size take unequal loads, milled cast iron separators fitting tight against the flanges of beams shall be provided. Other separators may be of heavy gas pipe with ¾ inch bolts made tight. All separators are shown in detail on plans.

Tie-rods. Tie-rods ¾ inch in diameter must be provided on all floors, and ⅝ inch in diameter in roof, as shown on plans. Each tie-rod must be made with two nuts, one on each end. Bent tie-rods must be rejected.

General. The purpose and intention of these specifications is to provide for complete work, including all necessary details and connections requisite for erection and safety, and for the development of the full strength of the structure. Such details are to be considered as specified, and are to be provided by the iron contractor without extra charge.

ERECTION.

Safety. All erection work shall be done in a safe and careful manner, and all the provisions of the State Labor Laws and City Ordinances relating to safety and erection of buildings shall be complied with.

Accidents. The contractor is to take upon himself all accident liabilities resulting from the erection of the iron work.

Bracing. Whenever the masonry is more than three tiers behind the steel work the contractor must put in temporary timber braces or steel cables or guys to keep all the iron work plumb until the walls are in place. This must be done to the entire satisfaction of the architect.

Setting Iron. In handling and setting iron pieces due care should be exercised to prevent beams and columns from falling, in order to avoid bending and heavy shocks. In driving and bending iron, wooden mauls should be used in preference to iron hammers whenever possible.

Bases. All bases for columns must be set to exact centre and to exact height, and no variation greater than 1/16 inch from the correct position will be allowed. The masonry contractor will bed all bases in position.

Columns. All columns must be set plumb and in proper line, and not less than 50 per cent. of all holes in column

splices must be filled in with ¾ inch temporary bolts as soon as each column is in place.

Beams. All beams must be set level unless otherwise indicated on plans. The elevation of wall beams and lintels is indicated on plans.

Derrick. The mast of the derrick must at all times be securely tied with steel guy ropes properly anchored. All beam and column connections immediately under the derrick shall be fully bolted before any iron is hoisted. The block under the mast shall be kept in place by solid timber braces and steel ropes. All iron work must be hoisted in a safe manner to avoid accidents.

Overloading. All possible cases of overloading must be avoided, and loads stressing any piece beyond the allowable working stresses will not be allowed. Beams supporting the derrick shall be shored at the mid-length with solid timber posts supported by beams on the tier below the derrick, in order to avoid overloading.

INSPECTION.

General. Before the commencement of casting or rolling the manufacturer must give the inspector due notice to that effect. All facilities should be given throughout the manufacturing processes for an adequate inspection. All pieces must be inspected by daylight, and all material shall be turned over for inspection on all sides at the request of the inspector.

Identification. All pieces must be marked for identification with the number of the original furnace heat, except that for pieces used to carry small loads the inspector may waive this requirement. All rejected material shall also be identified by permanent marks.

Stock. No stock material will be allowed as a substitute for new rolled material except in case of pieces used to carry small loads or when the material was tested and identified as above, and the inspector can judge as to its quality from undoubted records.

Records. Manufacturers shall keep open for the inspector all books or records giving information as to the quality of materials, and shall furnish the inspector with records of chemical analyses and copies of shipping invoices.

Manufacturers will give at least two days' notice before each shipment to the architect or his inspector. Manufacturers will also provide all reasonable facilities for a proper inspection.

Costs. Manufacturers shall furnish the inspector all test specimens, the use of testing machines, and all labor necessary to handle the material for inspection. Where shipments are made without inspection, or when due notice or proper inspection facilities have not been furnished, the additional cost of subsequent inspection will be borne by the manufacturer.

General Responsibility. Manufacturers, mills, foundries and shops are required to furnish satisfactory materials strictly in accordance with the plans and specifications, regardless of inspection, acceptance, or failure to inspect certain pieces of material.

CHAPTER VII.

Field Inspection of Minor Iron and Steel Structures.

In approaching the subject of field inspection of iron and steel it was found advisable to state in a few words the kind of work expected from an iron inspector in the field. The inspection of minor structures like small alterations has next been described, starting with simple store front alterations with and without column supports.

The more complex work, that of inspecting tall structures, will be taken up for convenience under several separate headings in the chapters following.

The work of an Iron Inspector in the field depends largely upon the stage the structure has reached at the time of the inspection. The following classification indicates in a general way the kind of work to be performed by the inspector:

1. To examine materials as to their sizes, shapes, workmanship and other qualities.

2. To see that all the materials agree with the approved plans and with the building laws.

3. To mark rejected materials for identification and to see that no rejected material is used in the structure.

4. To inspect the workmanship of the iron framing and to condemn bad work, thus promoting good workmanship.

5. To see that the erection is carried on safely and without danger to life and limb, and that the State Labor Laws or any similar laws or ordinances for protection of life and limb are not violated during any time while the construction work is in progress.

6. To inspect the derricks, guys and, in general, all the rigging in order to avoid accidents.

7. To see that no part of the structure is overloaded.

8. To see that the structure is properly braced and guyed during erection.

INSPECTION OF STORE FRONT ALTERATIONS.

Examining Materials Before Setting. Many errors can be conveniently avoided by examining the iron and steel

upon delivery and before the same is set in place. While such an examination is desirable in all cases, it can usually be performed by the architect's or the owner's inspector, who is at the job all the time and who can therefore check up and inspect the materials as they are delivered. This inspection is especially important in store front alterations.

Store Front Alterations. This group of alterations includes the partial transformation of dwellings or similar houses into commercial buildings by removing part of the front brick work to provide large show windows, and by supporting the masonry above these windows by means of iron or steel girders or beams; it also comprises the removal of piers of masonry in actual stores to allow room for larger show windows.

In both these cases the brick walls are usually shored up, the iron beams placed in their proper place, and the shoring removed as quickly as possible to avoid business losses.

The iron beams should be examined while in the street and before setting, because after erection the beams may not be easily accessible. Also, the beams may be covered up quickly, before being inspected, and if the beams are condemned it is very hard to replace them after the shoring has been removed.

Following points should receive careful consideration:

1. **Wrought iron beams** are substituted for steel beams of equal depth. The wrought iron beams can easily be identified by the fibrous appearance of the metal and by their heavy web and clumsy cross-section, which contrasts easily with the slender cross-section of standard steel beams. There are few wrought iron beams rolled to-day, as steel beams have greater stiffness and therefore greater load carrying capacity than wrought iron beams of equal weight. The only serious objections against wrought iron beams are their lower strength and their greater deflection as compared to steel beams. For small spans and dead loads the deflection may not be an important factor; as for strength the wrought iron beams are generally 20 per cent. weaker than steel beams of equal weight, and a careful refiguring by the architect or by the plan examiner of the loads to be carried by the wrought iron beams may bring the beams in question within the requirements of the law.

2. **Second-hand Material.** Nothing in the law prevents the use of second-hand material provided same is in good condition. Second-hand box girders and thin webbed beams heavily painted may have their webs badly corroded and

full of holes. Such iron should be struck with a heavy hammer or a crowbar enough strong blows to establish beyond question the condition of the thinner metal under the coat of paint. Examine the web also for holes filled in with paint; if there are enough of these holes to materially reduce the cross-section and weaken the girder the same should be rejected.

3. **Separators.** Double wall beams should be provided with separators not further apart than five feet. (Section 117, Building Code.) Beams 12 inches and over must have two bolts in each separator. This may be taken to mean that cast iron or steel plate separators must be used for beams 12 inches and over, or else two bolts could not be provided in each separator. Separators are used either for keeping the beams in proper positions at definite distances apart, or for the purpose of equalizing the loads carried by each beam when the load is applied eccentrically. Separators also increase the stability of each beam, lessening the tendency to overturning; they also stiffen the webs and prevent crippling in the web.

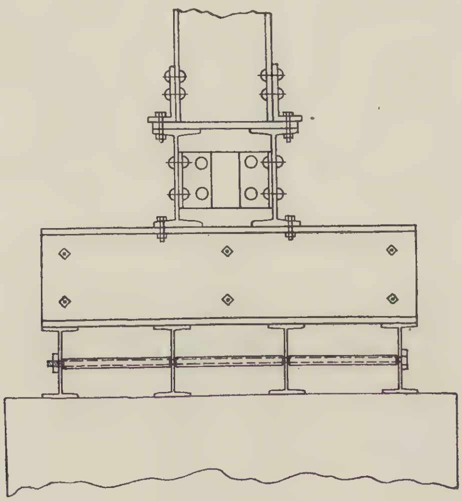


Fig. 12—Grillage.

Fig. 12 shows a column footing with standard one-inch gas pipe separators in the two lower sets of beams. The 12-inch beams have two pipe separators, one over the other, as required. All these pipe separators keep the grillage

beams in the proper relative position until the grillage is filled in and covered up with concrete.

The most reliable kind of separator is the one built of steel plate and knee angles, as shown under the column. The angles are riveted in the shop to the steel plate, then the other leg of each angle is riveted to one beam when the beams are not too heavy to handle together, otherwise the separator is shipped loose and bolted in the field.

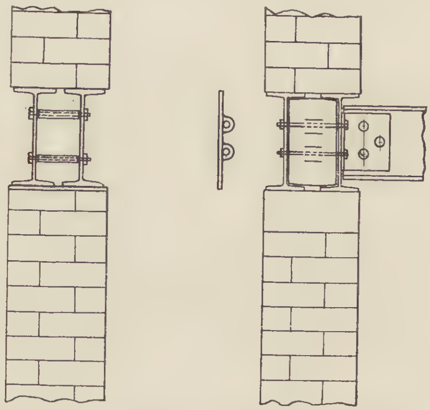


Fig. 13—Gas Pipe and Cast Iron Separators.

Fig. 13 shows the common gas pipe separator used in double wall beams to increase the stability of the iron beams and to prevent them from spreading apart.

Fig. 13 also shows the common or standard type of cast iron separator. Either this separator or a plate and angles separator should be used when the load is applied eccentrically, as in the diagram. The outside beam carries part of the wall load only, while the inside beam carries both wall and floor load. The two wall beams will not act together like one girder unless proper separators are used to tie the beams to one another. Pipe separators should not be used in such cases. The standard cast iron separator must be milled around the edges to fill in closely against the webs and flanges of the beams.

Fig. 14a shows a separator made of 3/8-inch plate and a steel flat bent to suit and properly bolted.

Fig. 14b shows channel separators.

Fig. 14c shows separators made of 3/4-inch rods with double nuts at each end.

4. **Common Defects in Separators:**

Separators not provided within 5′ 0″ center to center distance.

Using only one bolt in a 12-inch beam separator, instead of two, as required.

Omitting separators.

Using ¾-inch bolts without pipes.

Using pipes that are too short in length.

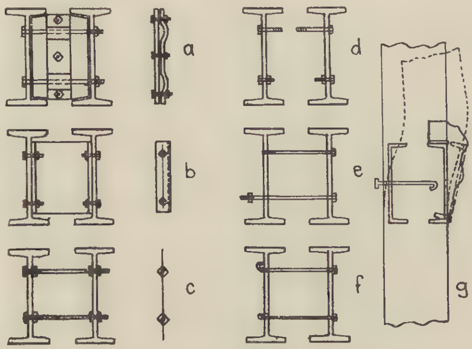


Fig. 14—Good and Defective Separators.

Using pipes with rough edges instead of sawing same off to a smooth edge.

Using deceitful short bolts instead of through bolts. Fig. 14d.

Using bolts too short or too long. Fig. 14e.

Using bolts less than ¾-inch diameter in 13/16-inch holes.

Using hook bolts instead of standard head bolts. Fig. 14f.

5. **Results of Defective Separators:**

In one instance separators have been omitted in 12-inch front wall channels. The channels were about 30 feet long and had shop punched holes for separators. Fig. 14g. Brick work and terra cotta were set for a height of two stories before providing separators. The channels began to spread, as shown dotted. Attempts were made to drive a ½-inch hook bolt in the inside and to catch the outside channel through a 13/16-inch separator bolt. Two stories of brick work had to be removed, also the terra cotta, and straight separators with sawed off pipes had to be provided. Hook bolts cannot be made sufficiently tight, and they should never be used.

Short bolts may cause leaving out the nut in the threaded ends. Long bolts may not be made tight, due to lack of

thread length. Iron washers may be used with the long bolts, but short bolts should not be allowed. In one case the excess length of some long bolts has been packed up with wooden washers. This is bad construction, as the wood may rot, thus leaving the double beams with loose separators.

6. **Strapping of Iron Work.** The steel beams supporting the walls of a building should be strapped or tied to the inner parts of the building so as to secure absolute stability. This is usually done by providing steel straps as shown in Fig. 15, under each brick pier between windows, and in all cases not less than three straps for a front of about 25 to 30 feet. Each strap is made of a steel flat 1½x⅜ inches and long enough to catch over four joists and to be bent up will be necessary at the anchored end.

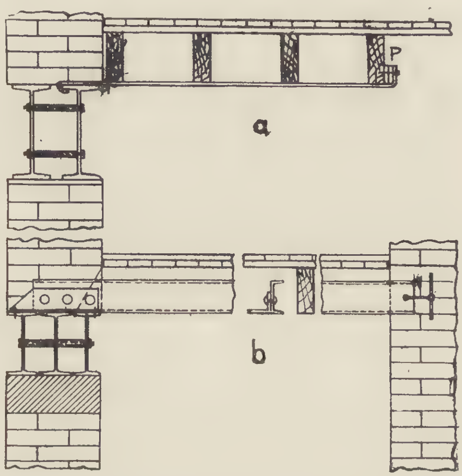


Fig. 15—Wall Beams and Ties.

Each strap is nailed to each joist at crossing points to prevent the strap from falling down, holes having been provided in the straps for this purpose. Packing should be provided at P, if necessary, to fill in the space between the strap and the last joist. The strap may be made to catch the outside beam or it may be passed in between the beams as shown in the figure. The last method avoids disturbances in the arrangement of the face brick. When the beams are too close together a notch may be made in the flange of one of the beams to make room for the strap.

When the top of the wooden beams is lower than the bottom of the steel beams, the straps may be placed under the steel beams and over the wooden beams with equally good results. Whenever possible the straps should be placed so as to avoid breaking through plastered ceilings which would have been left undisturbed otherwise.

The front beams may also be tied in by means of an angle or channel bolted to such front beams (Fig. 15b) and made to run alongside the floor construction to some interior wall or pier and anchored into same. This arrangement is conveniently used when the wooden floor joists run fore and aft or at right angles to the steel beams supporting the wall.

If the tie beam does not carry any load no template will be necessary at the anchored end.

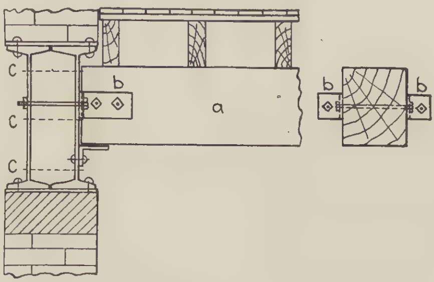


Fig. 16—Box-Girder tied to Wooden Beam.

a, 8 in. x 10 in. main wooden beam on a long span.
b, 6x3½x⅜ angles with ¾ in. bolts.
c, separators.

Another arrangement is given in Fig. 16. It shows through bolt strapping of a double-beam steel box girder to 8x10 inch wood beams running fore and aft. There are two strap angles, each with two bolts through the timber and one through the girder.

7. **Usual Defects in Strapping:**

Omitting straps.

Using straps less than 1½x⅜ inch cross-section.

Using short straps which do not catch on four beams.

The inner end of each strap is not bent vertically beyond the fourth beam.

Straps are loose and do not fit, no packing being provided. In this case either pack the inner end of the strap with wooden pieces or pack the outer end with iron wedges, or even a piece of a round iron bar or a piece of an angle

placed against the beam so as to fill up the space between the strap and the beam.

8. Templates. Where iron wall girders rest on masonry templates are provided under the ends of such girders to uniformly distribute the pressure. The sizes of templates required by the Code are as follows:

For girders over 12 ft. span, stone templates 10 inches thick.

For girders under 12 ft. span, stone templates 5 inches thick.

For lintels over 6 ft. span, stone templates 5 inches thick.

For lintels under 6 ft. span no template is required, but each end must bear 5 inches on the wall.

Steel plates of equal strength may be used instead of stone templates. In addition all wall bearing beams must have iron or stone templates and wall anchors, except beams less than 6 inches in depth when spaced not over 30 inches centre to centre.

Steel templates should be well grouted, so as to bind well to the masonry.

The sizes generally used are as follows:

For 3, 4, 5 and 6 inch beams, 6x6x3/8.

For 7 and 8 inch beams, 8x8x1/2.

For 9, 10 and 12 inch beams, 10x10x5/8.

For 15, 18, 20 and 24 inch beams, 12x12x3/4.

Where larger size templates are required, grillage beams with separators may be used instead of templates to distribute the load on the masonry.

All templates must be placed flush on edge with the inner face of the wall, as in Fig. 17a. Where the plate is placed too far in, the iron beam upon deflecting may crush the wall at the inner edge. See Fig. 17b.

When the templates are rectangular and of sufficient thickness, they should be placed with their longer edge along the inner edge of the wall.

In some cases box girders with a wide bottom plate are used. These plates can not be considered as equivalent to templates, no matter how much they bear on the wall. A template when well set forms part of the wall and sticks to it, thus tending to uniformly distribute the load over the pier area. This template does not deflect with the girder, as shown in Fig. 17c, which represents the side elevation of a box girder made of two 10 inch beams and two 1/2 inch plates. On the other hand, if the template is omitted the bottom plate of the girder will deflect with the girder and will bring a concentrated load along the very edge of the wall, as in Fig. 17b.

9. **Usual Defects in Templates:**

Omitting templates.

Using stone templates of less thickness than required by the Code.

Placing the templates inside the wall and beyond the inner edge of the wall.

Placing templates too low and raising the end of the girder to the proper level by means of wood or slate wedges.

Using small templates and thus overloading the masonry.

Using thin templates, which tend to bend under the super-imposed load.

Using cracked and otherwise defective stone templates or cast iron plates.

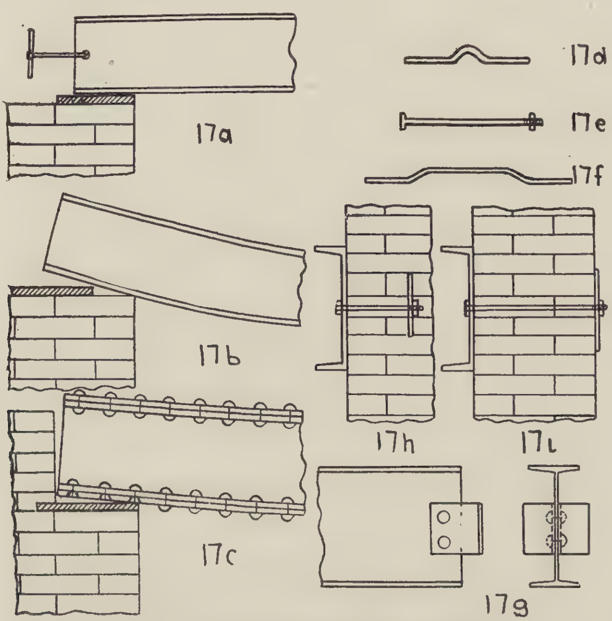


Fig. 17—Templates and Wall Anchors.

When the templates are too low the difference should be made up by using thin steel plates on top of the original low plates, and of the same length and width as the main template. Or the template may be raised to the proper elevation by means of small wooden wedges forced underneath and the space under the template filled in with good cement mortar. When this has set sufficiently the wedges are pulled out and the openings thus left are filled in with grout. No load should be placed upon the steel template until the mortar underneath it has completely set.

10. **Wall Anchors.** The main purpose of wall anchors is to secure greater stability for the walls. There is a large variety of anchors used for the purpose and some are shown in Fig. 17.

A good anchor must have a large area in contact with the mortar, hence the round anchor shown in Fig 17d is commonly used. This anchor is made of a ¾-inch round bar and should be about 12 inches long. It is often specified in government work and is also known as a government anchor. The plain bolt anchor, Fig. 17e, is easily obtainable. The bolt anchor and riveted anchor have the advantage that, being once put in place, they can not be removed by other mechanics as easily as the so-called government anchor before the masons brick these anchors in. Anchors which are not put in ahead of time by the iron setters are liable to be left out by the masons.

Fig. 17f shows a ¾-inch round anchor sometimes employed in connection with beams used in pairs.

The riveted two-angle anchor shown in Fig 17g is especially good for sidewalk beams; they tie the street retaining wall to the main building and can not be removed before bricking in.

The common wall anchor, Fig. 17h, should be used in all cases when the iron work is about 12 inches or more from the outside face of the wall. Not less than 4 inches should be allowed between the anchor and the face of the wall. This is the anchor commonly used in tall buildings, and is usually made of a ¾-inch bolt with a 6x6x5/16 plate.

Fig. 17i shows an excellent form of through wall anchor. The ¾-inch bolt passes through the whole thickness of the wall and is provided on the outside with either an iron star or a large washer.

In alteration work, whenever a wall is broken into for the purpose of resting an iron beam on same, it is good practice to disturb the old work as little as possible. Hence in such cases the double-angle anchor, either riveted or bolted, is preferable. Little advantage is gained, however, in such work with any kind of an anchor, as upon patching up the wall around the beam in general only the patchwork will stick to the beam and anchor, while the main wall will adhere very little to the new material unless unusual care and good workmanship are secured. Under such conditions, if the building is only a few stories in height, and when the wall is not an xterior wall, a straight beam end without an anchor, resting on the wall and surrounded with good Portland cement mortar and brickwork, may be found preferable.

STORE FRONT ALTERATIONS INVOLVING COLUMNS.

This is a very common form of store front alteration. Instead of resting the front wall girders on party walls or on brick piers, the two ends of these girders rest on top of columns of iron or steel.

The columns must be of the right weight and size, must be plumb and straight. They must rest on base plates of dimensions approved in the original plan. They must be bolted on top with not less than four ¾-inch bolts in each column.

The beams must agree in size and weight with the approved plans; must have separators not further apart than 5 feet centre to centre, and must be well strapped. All ironwork must be painted before and after erection.

The common defects mentioned in relation to beams in the previous chapter are often found, also, in these alterations.

In addition, we shall mention faults found in columns and their connections:

1. Lightweight iron.

Iron heavier than called for in the approved plans, but the shapes and materials are contrary to approved plans.

For instance:

Using built-up columns instead of Bethlehem columns.

Using cast iron columns instead of steel columns.

Using standard beams for columns instead of Bethlehem columns of equal weight. This is one of the most dangerous changes when made without first figuring out the load that can be safely carried by the new columns. To make this point clearer consider the following figures:

An 8 inch Bethlehem column weighing 32 pounds per foot is good for 55 tons when 12 feet long.

A 6 inch round cast iron column ¾-inch metal, weighing 39.2 pounds per foot, is good for 66.4 tons when 12 feet long.

A 5 inch round cast iron column ¾-inch metal, weighing 31.7 pounds per foot, is good for 52 tons when 12 feet long.

A 12 inch standard I-beam 31.5 pounds per foot is good for 32.1 tons when 12 feet long.

It is easily seen what might happen when a 6 inch cast iron column is replaced by an 8 inch Bethlehem steel column, or when a 5 inch cast iron column is replaced by a 12 inch standard steel beam.

2. Steel plates and stone blocks under the bottom of the column are defective, of smaller area and less thickness than required in the approved plans.

3. Omitting plates on top of open back cast iron columns. These plates make the load more uniformly distributed and shall not be omitted. They are required by the Building Code.

4. Erecting unpainted columns and placing brickwork around same before painting.

5. Using bolts less than ¾-inch diameter in the top flanges of columns in connections of beams to columns. Using less than four ¾-inch diameter bolts in the top flanges of cast iron columns, same being contrary to the Code.

6. Using ⅝-inch bolts in defective 13/16 holes instead of reaming out the holes and using ¾-inch bolts.

7. Leaving out part or all the bolts.

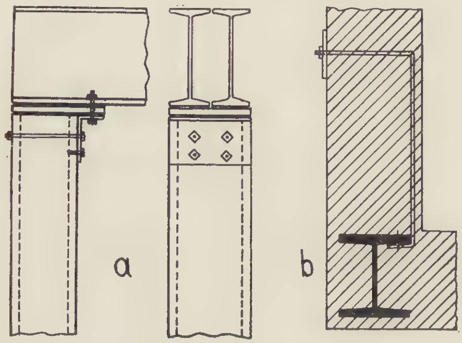
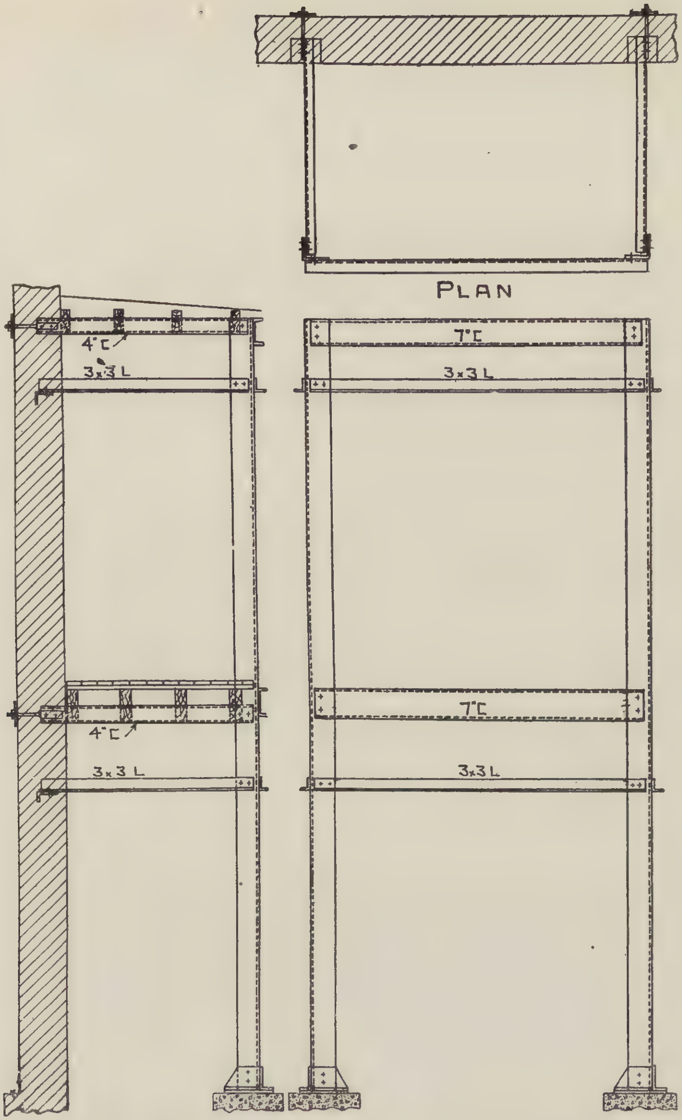


Fig. 18—Columns and Straps.
a, 8x10x1 in. cast iron column supporting two 12 in. steel beams; b, 10 in. Bethlehem column strapped with ¾ in. rod through wall.

8. In some cases second-hand cast iron columns without top flanges have been used. The lack of flanges can be remedied by an arrangement shown in Fig. 18a. A steel knee angle with one line of through bolts and one line of tap bolts may be used. A plate is put on top and then the beams are drilled to fit and are bolted with ¾-inch bolts. The diagram shows a column next to an adjoining wall. Other columns may have one steel knee angle on each side.

9. The steel or iron columns may be out of plumb; the steel beams may project beyond the party line. All beams projecting beyond the party line should be cut short and all columns shall be plumb.

The beams on top of the iron columns are strapped to the wood joists as before stated. If the work is done right



Side Elevation. Front Elevation.

Fig. 19—Store Front Framing anchored through wall.

this will also help keeping the columns plumb. In case of fire, however, the wood joists may burn and the beam straps may become useless. For this reason in good work ¾ in. round anchors are used, passing through each column every 4 feet or so in height, and then into the side or party wall, as in Fig. 18b. All spaces around these anchors are then filled in with a good cement mortar.

One more type of store front construction will be considered. Fig. 19 shows the side and front elevation and the top view of a common show window extending two stories above the ground. The steel frames for such show windows must be well anchored to the main building. The uprights are usually made of steel angles, which are tied to the main structure by channels or angles. Whenever possible such ties should be bolted to the ironwork of the main building. In the figure, however, is shown a case where no iron work was within reach, and the whole window frame is tied to the front brick wall.

The 4 inch channels carry the roof and intermediate floor construction. They are provided with anchors made of ¾ inch round bars passing through the wall and through 6x6 steel plates on the inner face of the wall. The other end of the anchor is welded to a 1½x⅜ flat piece, through which two ½-inch bolts are passed into the 4 inch channels. Or the whole anchor may be made in one piece from a 1 inch round bar. In either case a thread is cut into the anchor and a nut is provided, as shown in the side elevation. As the 4 inch channels carry the roof and floor, steel templates have been provided under their wall-bearing ends. See Fig. 19 Plan.

The 3x3 inch angles carry no load except, perhaps, the weight of some window panes. The purpose of these angles is to break up the unsupported length of the main angle uprights and to stiffen the whole frame. These angles form a continuous band all around the steel frame and should be anchored to the wall with clip angles as shown.

The main uprights must be properly bolted and provided with a suitable shoe and plate at the bottom.

The common defects encountered in this kind of work are as follows:

1. Anchors through wall are omitted, and the floor-carrying channels simply rest a few inches on the brick work. This must not be allowed. Where the anchor strikes into a partition or an interior brick wall the anchor may be placed on a slant, or it may be bent to avoid the partition, if necessary.

2. Omitting templates under floor-carrying beams.

3. Omitting intermediate bracing angles.

4. Defective bolting.

5. Providing no shoe at the bottom of the main uprights.

6. Omitting plate under the main uprights.

7. Using lighter material than called for in the approved plans.

8. Erecting unpainted iron or omitting a second coat of field paint.

CHAPTER VIII.

Hoisting Iron Work.

KINDS OF HOISTS.

Before any columns are set in their final position one or more derricks are installed on the premises for hoisting the iron. A hoist is any machine used for raising and lowering weights. There are several kinds of hoists:

1. **Cranes.** A crane is a hoist which in addition to raising the load can also be made to move it in a horizontal direction. (See Fig. 20.) A crane consist chiefly in a revolving vertical post or mast, a projecting jib or boom, and a stay for sustaining the outer end of the jib. The stay may be either a tie or a strut. The post, jib and stay do not change their relative positions.

2. **Derricks.** A derrick (Fig. 21) differs from a crane chiefly in the fact that the stay is always a tie, consisting of a rope or chain, which may be shortened or lengthened at will, thus raising or lowering the free end of the jib or boom. This in turn revolves about an axis passing through its lower end and attached near the foot of the mast. In a derrick the post, boom and stay change their relative positions. The boom can be made to raise loads vertically at higher elevations than in the case of cranes. For this reason derricks are generally used in hoisting iron in constructions.

3. **Shear-poles** with guys consist of two masts brought together at the top, and tied at the top with one or more guys (Fig. 22). This device is used for hoisting small loads only.

On large jobs steel derricks, with mast and boom made of several sections of angles and lattice work, are generally used. Steel masts and booms are usually over 100 feet long. Wooden masts and booms are of all sizes, generally less than 100 feet in length. A large boom reaches far out into the street and covers a greater range of the building at the same time.

The first time a derrick is set on a job the erector will drive five or six iron bars or hooks around the edges of the lot. These hooks are called the dead men, and are used to

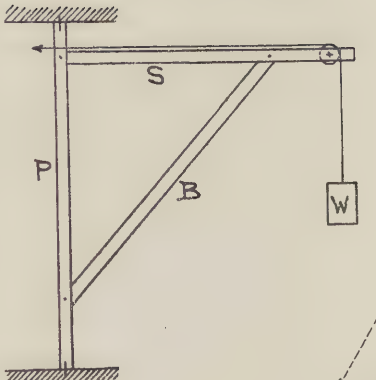


Fig. 20—Crane.

P, post or mast;
B, boom or brace;
S, stay: strut or tie.

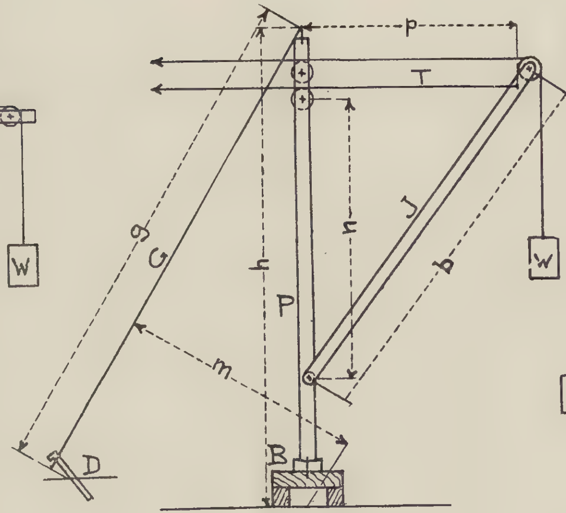


Fig. 21—Derrick.

P, post or mast;
J, boom or jib;
T, tie rope; B, Block; G, guy-rope;
D, dead man.

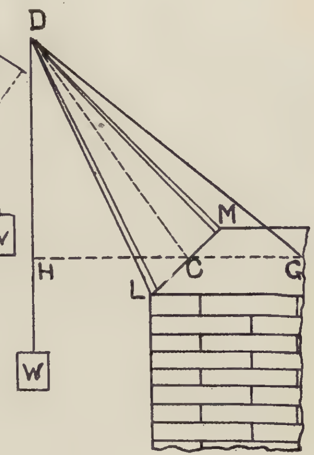


Fig. 22—Shear pole.

DL, DM, posts.
DG, guy-rope.

anchor the guy ropes that hold the mast in place. Good dead men are made from steel rope coiled around several times and strongly clamped together. A round ¾-inch bar one foot long passes through this coil. The whole is placed in the concrete under the grillage or in between heavy grillage beams, with exception of one end of the loop which projects outside. This is used to anchor the end of the guy rope. In some cases, where another building on the adjoining lot has some exposed column or other good points of anchorage the erector may take advantage of such points and use them as dead men with the consent of the owners concerned. After the dead men, the block is set in the desired place and spiked to prevent sliding. Heavy 12x12 pieces about 8 to 10 feet long may be required under the block to distribute the load. The mast is then tied on top with all guy ropes while the mast is still on the ground in a horizontal position. Then the mast is raised to a plumb position over the block, by cleverly manipulating the guy ropes and by shoring or by using a small hand derrick. All guy ropes are provided with turn buckles; by means of these the ropes are all set in tension and the mast is made plumb. Then the boom is raised in place by means of a rope tied to the top of the boom and passing over the pulley near the top of the mast. A pin is passed through the lower end of the boom and the derrick is set.

After the erectors have set as much of the iron as could be set from one position of the derrick, the latter is raised. All hands help in raising the derrick, and some heavy derricks have thus been raised in two or three hours by ten or twelve men. The beams upon which the derrick is to rest are carefully and completely bolted at their ends. If these beams are not sufficiently strong, and as a precaution against overloading, 12x12 in. wooden blocks or sticks are provided vertically under the derrick beams, reaching from under the new position of the derrick to the iron beams of the tier below. Using the boom as a vertical post, the mast is raised, usually two tiers at a time. The mast is then guyed and plumbed, and the block under the mast is securely tied in place in its new position. Using now the mast and its pulley on top, the boom is raised to the same floor and placed with the lower end in its pin connection as before. The derrick is then completely set.

Where two or more derricks are used on a job, each one in turn may be used to raise the others. This saves considerable time and labor. As an interesting suggestion it may be mentioned that in one instance a seventeen-story building

was erected next to a twenty-story building by using only a boom placed on top of the twenty-story building.

Some derricks are run by electricity supplied from the street distributing lines. Most of the derricks, however, are run by steam used in full stroke engines. Where electricity is used there is no coal to be stored up, no ashes nor smoke. No fuel is wasted during lunch hours or after the work is stopped for the day. Electric derricks should be used especially in small, narrow buildings, where it is difficult to back up teams for coal or for other materials.

Stresses in Derricks. Consider a derrick in the position when the load is exactly opposite one of the guys G. (Fig. 21.) In practice the two pulleys shown near the top of the mast are placed on the same axle. Let W be the load in pounds. Then,

the total stress in the boom J is $W \times \frac{b}{n}$ lbs. where

$b =$ length of boom in feet, and

$n =$ distance in feet from the pin at the bottom of the boom to the near end of the tie T.

Total tensile strength in $T = W \times \frac{p}{n}$ lbs.

Total stress in guy-rope $G = W \times \frac{p}{m}$

Total compression in the mast $P = W +$ stress in guy-rope $\times \frac{h}{g}$

Stresses in Shear Poles. Consider the two masts DL and DM replaced by a single mast in centre, DC. Also, let us take up first the case of the shear-pole with only one guy-rope on centre, like DG. Let $W =$ total load in pounds and a, b, p, n, k distances, as shown in the figure and expressed in feet, viz.:

$a = GH$; $b = DC$; $n = DH$; $k = CG$ and $p =$ perpendicular distance from C to DG.

We then have:

Total stress in $DC = \frac{ab}{nk}$ pounds

Total stress in $DG = W \frac{a\text{-}k}{p}$ pounds

The stress in either mast will be found by multiplying one-half the stress in DC by $\frac{DL}{DC}$

Where two guy ropes are used, the stress in either guy-rope will be found by multiplying one-half the stress in DG by $\frac{\text{length of one guy-rope in feet.}}{\text{D G}}$

Ropes. Guys for shear-poles are often made of hemp or Manilla rope. A hemp rope one inch in diameter has an ultimate strength of about 6000 pounds, and a safe working strength of about 800 pounds. Manilla ropes are slightly stronger. Guys for derricks are usually made of iron or steel wires twisted into strands, which in turn are twisted into wire ropes. Iron ropes one inch in diameter have an ultimate strength of about 35,000 pounds, and a safe working strength of about 6000 pounds. Steel ropes one inch in diameter have an ultimate strength of about 50,000 pounds, and a working strength of about 8000 pounds.

DERRICK ACCIDENTS.

Here are a few of the most common derrick accidents:

1. **Defective Anchorage.** The dead man may slide out. An accident of this sort is likely to take place after a heavy rain, where the dead men have been placed into soft ground. In one instance two men were killed when the derrick upset due to the loosening of one dead man.

2. **Slipping of the Block.** The block under the mast may not be safely anchored against sliding. This may cause the derrick to upset.

3. **Overloading.** This kind of accidents are very serious. They often cause the mast to fall through the floor upon which it rests, and to get clear down to the cellar.

In one case an overloaded derrick on the second tier fell into the cellar, tearing away connection angles and completely wrecking the panel below it. Steel beams were so badly twisted that they had to be entirely replaced, and two men were injured.

4. **Defective Ropes.** Overloading may also be due to the use of defective hoisting ropes, when such ropes are used to carry excessive loads.

In a 20 story building several erectors were busy trying to bring a column in a vertical position preparatory to setting it on the 8th tier. As soon as the column was vertical but not in place, the sling broke and the column fell from the 8th story to the cellar. It broke through the planks on the 8th tier,

twisted several beams, crashed through three tiers of filled in floor arches and injured seven people, some of them very severely.

5. **Insecure Pulley.** As mentioned before, there is a pulley fastened to the block at the bottom of the derrick, and the rope from the engine passes under it. It may happen that the pulley gets loose, as it did in an accident, investigated by the author. The pulley jumped off the block while the derrick was loaded (Fig. 23). In an instant the rope between the drum and the top of the mast became one straight line throwing the sidewalk bridge over 12 feet up in the air. Two persons were crossing the bridge at the time; one jumped off, the other was thrown up and fell directly over the engine.

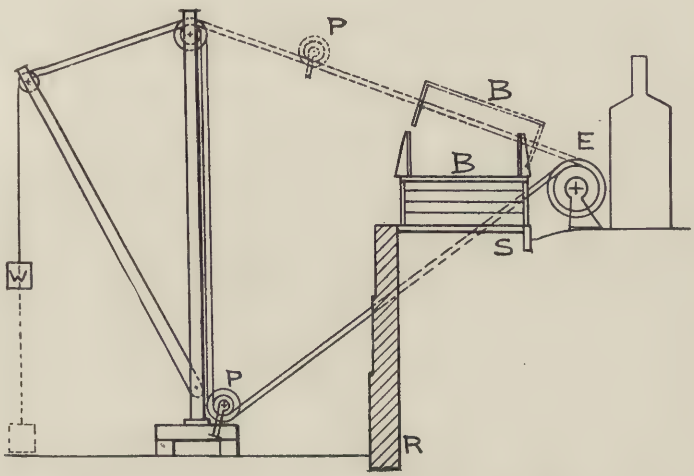


Fig. 23—Derrick Accident. Pulley PP got loose

R, Retaining wall; S, Sidewalk; B, B, Side walk Bridge; E. Hoisting Engine.

6. **Engine Breakdown.** Perhaps the most dangerous accidents may result from defects which will set the engine out of order while a load is partly on its way up.

In one instance the load was just about 2 feet above the bridge when the piston cylinder burst. The steel fell on the bridge with no consequences.

In the case of a 20 story building about four tons of steel were hoisted up to the 18th tier, and the engineer was ready to boom in the load when a cog in a gear wheel got out of order and allowed one rope to unwind. This rope governed the boom motion. With a thunder like that of an explosion

the 80 ft. steel boom crashed against the steel work of the 18th tier and sheared itself into two halves. The upper part turned a half circle in the air and stuck in between the beams of the 15th tier. The lower half was a useless mass of junk on the 18th tier. As for the load of steel, it fell into the street next to the edge of the side-walk shed and buried itself for over two feet into the asphalt pavement near the curb. All the iron in the street was so badly twisted that it had to be replaced. Several beams near the 18th tier were also partly deformed. None of the columns already erected were seriously damaged.

7. **The Engineer.** Serious accidents could also happen when the engineer running the derrick is not sober. Everybody around the building would then be in danger.

8. **Ignorance and Misjudgment.** Many accidents are due to these causes. An example will illustrate this group:

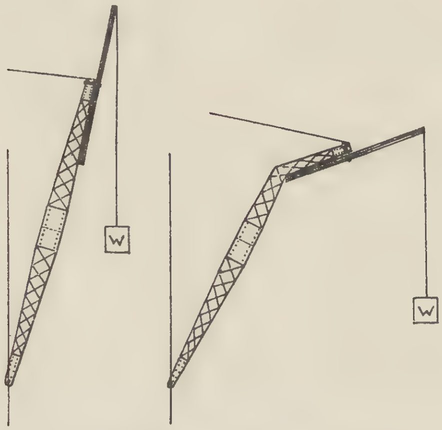


Fig. 24—Derrick Accident.
Boom made longer by using several boards. Before and after booming out.

In erecting a 20 story building by using two derricks, it was found that the boom of neither of them would take in a certain corner column. The booms were too short. The foreman stretched one boom (Fig. 24) by tying to it a bundle of four planks about 18 feet long. He then tied a rope to the new end of the boom and attempted to hoist in this manner a

column weighing three tons. The boom of course buckled and was out of commission in an instant. A new and larger derrick was finally used.

From what was previously stated it appears that derrick accidents are at times very serious and most regretable. It is incumbent upon the inspector as well as upon the erection superintendent of each job, to carefully examine all parts and accessories of each derrick as often as possible, in order to avoid accidents and injuries to men and structures.

CHAPTER IX.

Iron in Retaining Walls and Footings.

RETAINING WALLS.

In the erection of tall buildings, as soon as the excavations will allow, and as early as possible, sheath piling is driven along the sidewalk and the material is removed to make room for a retaining wall. There are three kinds of retailing walls in common use:

The most usual is the brick retaining wall. The Code requires that such walls shall be laid in cement mortar, like all the walls below curb, and the width of the retaining wall at the base must not be less than ¼ of the height of the wall. No iron is used in this kind of retaining walls.

The most graceful retaining walls which in the same time are stronger and take up less room in the cellar, are the reinforced concrete walls. One inch reinforcing bars spaced about 18 inches on centres vertically, and cross bars about 2 ft. on centres and about 1 inch thick are commonly used. Of course in walls reaching 30 to 40 feet, brick work may be out of question and the concrete wall will be designed in the usual way. The only objection to concrete retaining walls is the need of forms and the time lost in the setting of the concrete.

A third form of retaining walls often reaching over 30 ft. is sometimes used. This consists of heavy channels, placed vertically against the embankment about four feet apart, and braced against the main structure by means of steel beams, and with circular brick arches in between.

PIERS FOR COLUMNS.

For tall buildings in general the column piers are carried down to rock, using caissons if necessary. Where the rock is not far from the proposed cellar bottom, the walls between columns are also started on rock. Where caissons are used or where the rock is too low, steel beams are placed from column pier to column pier, and then the brick wall is started on top of these beams. Where the ground is soft and the rock is not within economic distance from the surface spread footings or piles may be used.

For lighter structures the piers may be left out, and the columns may rest directly on a spread footing carried by the

soil at the bottom of the excavation. Where no piers are used the Building Code allows a bearing capacity of:

1 ton per square foot on soft clay.

2 tons per square foot on clay and sand in layers, wet and springy.

3 tons per square foot on loam, clay, or fine sand, firm and dry.

4 tons per square foot on coarse sand, stiff gravel or hard clay.

These values are allowed where no tests are made. In all doubtful cases or where the owner wants a larger bearing allowance the Building Department will make tests at the expense of the owner. These tests are generally carried out as follows:

Upon a timber platform constructed for the purpose, the load per square foot which is proposed to impose upon the soil is first applied and allowed to remain undisturbed for at least forty-eight hours. During this time measurements are being taken once each twenty-four hours or oftener in order to determine the settlement, if any. After forty-eight hours 50 per cent of the first load is added, and the total load is left undisturbed for at least six days, careful measurements and reading being taken once in twenty-four hours, or oftener, in order to determine the settlement. The test is not considered satisfactory or the result acceptable unless the proposed safe load shows no appreciable settlement for at least two days and the total test load shows no settlement for at least four days.

The accepted safe load shall not exceed two-thirds of the final test load.

Piers. Before a pier is built, the pier hole must be inspected and approved. Where piers have to go down to solid rock, a man gets into the pier hole and sounds the bottom with a crow bar. Good rock is known by its general appearance and by a fairly clear ringing sound which it gives when struck with a bar. All soft spots must be cleaned out before the pier hole is approved. In some cases, although very seldom, these tests fail to indicate to the inspector whether solid rock, or simply a large boulder has been struck, unless great care is exercised.

Sometimes piers have been erected on top of old sewers or old well holes. These are dangerous cases and mostly met with in smaller buildings where the excavations are not carried far below curb.

After the pier bottoms have been approved, they are filled in with a mixture not poorer than 1 cement, 2 sand, and 4

broken stone or gravel. This is required by the Building Code. Each pier must be brought to the proper elevation on top,, and must be allowed to set hard before placing any load on top of it.

If after setting the piers come too high, on account of incorrect levelling, the top of the piers are cut down to within ¾ in. below the bottom of the column footing, whether it be a cast iron base or a grillage. This ¾ inch space allows for proper grouting.

In one case about fifty piers came too low by from 2 to 4 inches, all due to the leveler's mistake in starting from a wrong bench mark. Wooden forms had to be built around each pier, after the pier surface was made very rough; water was abundantly supplied to flush the pier and then a rich concrete was dumped on top to the required elevation. In order to make absolutely certain that these instructions were carried out, the builder cut down not less than one foot from the top of each pier. This insured a real rough surface of contact between the new and the old work.

For piers carried down to rock in caissons, the Code allows fifteen tons per square foot. For piers carried down to rock in open trenches or in sheet piling, only eight tons per square foot is allowed. This difference is due to the fact that in caisson work the caisson helps making a pier of a uniform cross section. The caisson will keep the mass together until set, and even then the caisson as a rule is left in place, and this adds some more strength to the pier. On the other hand in open trenches the pier may be irregular in cross-section, and the grout between stones may be lost by absorption into the soil, making the pier useless near the edges.

For piers carried down in caissons to gravel or hard clay, the Building Code allows ten tons per square foot.

Loads as high as 30 tons per sq. ft. may be allowed on good rock, where the piers are reinforced near the top by two or more rows of horizontal ½ in. steel round bars, placed about six inches on centres and about six inches apart vertically.

GRILLAGE. Rolled beams, channels or girders are generally used to distribute the column loads upon the top of the piers. The Building Code requires that all grillage beams shall be provided with proper bolts and separators, to keep them in place at a proper distance apart. It is also specified that all grillage must be inclosed and filled in solid with concrete. This is usually done by setting the grillage on wooden wedges, at the proper elevation and about ½ in to ¾ in. above the pier. A form is then built around the grillage and the

concrete poured in. Where the beams are too close together, grout, or fine gravel concrete will have to be used to fill in the spaces in between the beams.

Separators are placed to keep the beams properly spaced. In the same time separators stiffen the web of the beams and for this reason they are generally placed directly under the column. The separators for grillage are mostly one inch gas pipe cut to length, and provided with ¾ in. bolts. Other means for stiffening the webs of grilliage beams and for preventing them from crippling under the load, is to use heavier standard beams with thicker webs, or two channels back to back with a plate in between and riveted together, or even stiffener angles against the webs of grillage beams like in an ordinary plate girder.

Where two layers of grilliage are used under a column, the upper grillage in good work is bolted to the lower grillage. Some engineers insist however, that a space of about ½ in. should be left between the two grillage layers for grouting. Of course a grout of one part cement and one sand in such a thin layer will stand about six thousands lbs. per sq. inch before being crushed into powder and the objection that this grout will be crushed under the load may be disregarded. The reason for grouting in between rather than having the grillages in contact is that rolled sections are seldom of exactly the same depth. In fact their depth will vary in some cases more than ⅛ in. Consider now a column footing made of a lower and an upper grillage with no grout in between the two, and with the upper grillage consisting of three I beams. If, for instance, the middle beam of this upper grillage is not of full depth by ⅛ in., such a beam will be useless, because it will not carry any load until the other two beams, overloaded as they may be, will cripple in the web for ⅛ in. Grouting in between the two layers would tend to avoid these.

CHAPTER X.

Cast Iron Bases and Their Inspection.

DETAILS OF A CAST IRON BASE. The main parts of a cast iron base are as follows:

The Barrel, is the central part of the base, and has the form of a closed chamber, usually circular or rectangular. The rectangular form is shown in the base in Fig. 25.

The upper part of the barrel is covered by the **Top Flange** of the base, upon which rests the column. This top flange is provided with a hole in the centre, for grouting purposes. This grouting hole is cored, and is at least 3 inches in diameter. In addition there are four bolt holes near the corners of the top flange. These holes are very accurately drilled and are used in achoring the column to the base by means of ¾ in. or 1 in. diam. bolts.

The lower part of the barrel rests on the **Bottom Flange** of the base. This flange spreads the load over the pier area. Like the top flange, the bottom flange is provided with a 3 in. grouting hole in the centre, and with a number of 1½ in. diam. grouting holes all around the barrel. All these holes are cored, not drilled.

The barrel and the two flanges are tied together into one solid mass by means of a number of **Ribs.** These ribs are at least 1 in. in thickness, and the longer ribs at corners are usually of greater thickness than the interior ribs.

All around the edges of the bottom flange, the cast iron bases are usually provided with a vertical rim, about 3 inches in height and at least one inch in thickness. This rim is known as the **Compensation Flange.** It greatly increases the load carrying capacity of the base, and stiffens the joints between ribs and the bottom flange.

TESTING CAST IRON BASES. In the case of small loads the bases may rest on a steel plate on top of a pier, or even directly on the concrete pier as in Fig. 25. These bases are often dumped into the excavation before the derrick is set. They are tested by tapping with a hammer. Good bases will stand the hardest blows a man could deliver with a light sledge hammer. The same method of testing applies also to cast iron columns. Good castings give a clear ringing sound on tapping. The casting is gray, soft, with small crystals and is

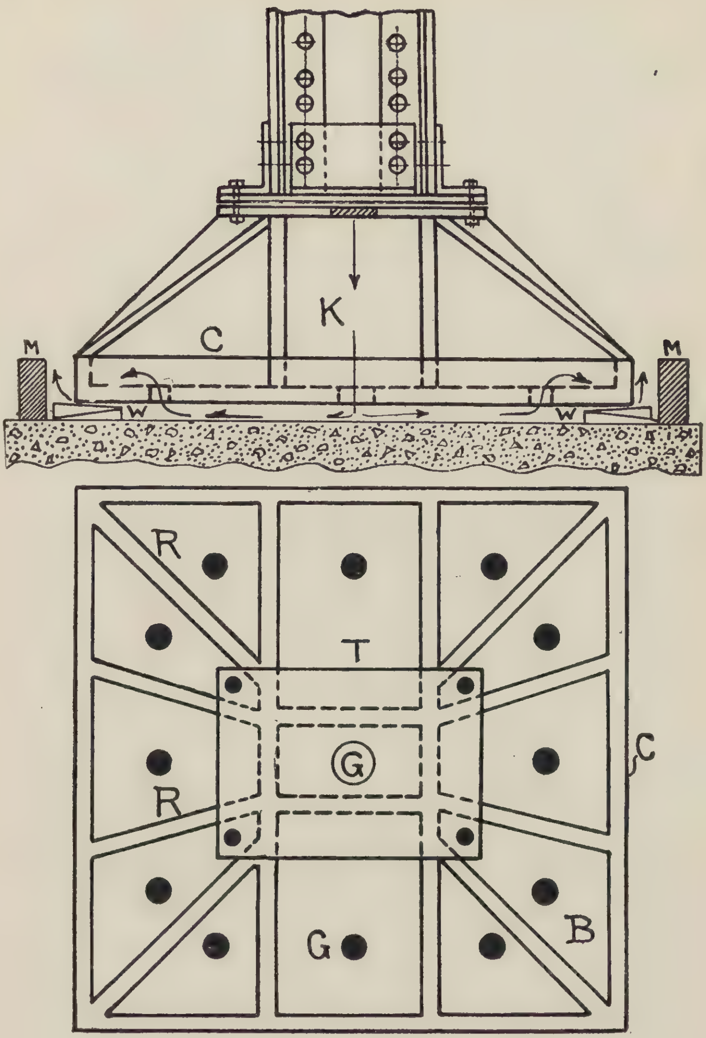


Fig. 25—Details of a Cast Iron Base.

T Top Flange. B Bottom Flange. K Barrel. C Compensation Flange. R Ribs. G Grouting Holes. WW Wooden Wedges. MM Bricks. Arrows indicate the flow of grout.

easily indented. Sand holes or blow holes are detected by a dullness in the sound. Cracked bases give also a characteristic sound which is easily distinguished. Warped bases are likely to have internal stresses due to unequal contraction or to other defects in manufacture and should be rejected; the same applies to bases of incorrect dimensions.

Repeated Inspections. Cast iron work must be repeatedly inspected. Bases which have been approved upon delivery may be cracked in handling.

In one case bases were made to slide on two timber guides running from the sidewalk to the bottom of the excavation. One base left the guides and struck a boulder. Luckily the base was smashed. Should the base have been cracked only, it is doubtful whether the particular iron foreman would have had the honesty to notify the inspector to this effect. He would have probably taken chances. As it was, a new base had to be obtained, but this caused several days delay in that part of the job.

In another case in a 12 story building, a steel beam fell down into the cellar and broke part of a base and more than half of the lower flange of a heavy 15 inch case iron column. The structure already eight stories high, had to be shored up and the column replaced.

SETTING CAST IRON BASES. Bases resting directly on grillage are bolted on top with four ¾ in. bolts to the steel or cast iron columns as in Fig. 25. Four pairs of wooden wedges are placed under the base when it rests directly on the pier. The base is centred and raised to the proper height. The clearance between base and pier should not exceed ¾ inch. Next a mixture of one part cement to one or two parts sand is prepared and this grout is poured through the top of the barrel, whence it penetrates under the base, comes out through the grout holes and overflows the compensation flange. Bricks are placed on edge all around the base to stop the grout from spreading.

Common Defects in Setting. It sometimes happens that the holes in the bottom of the column do not match with the holes in the top flange of the cast iron base. A drift pin can not be used to enlarge the holes and make them match, as this may crack the casting. In poor work, one of these methods is followed:

1. Omitting bolts altogether.

2. Using bolts of smaller diameter and with or without washers.

3. Using bent bolts.

In good work such holes are made to match by enlarging the opening by means of a hand or a compressed air reamer. After the holes have been lined up, the proper size bolts are put in.

Bolts without nuts and loose bolts are very common on jobs which are poorly supervised.

CHAPTER XI.

Cast Iron and Steel Columns.

The columns mostly used in tall buildings are steel columns. During the past few years there have still been erected several loft buildings with cast iron columns, some of them being twelve stories in height.

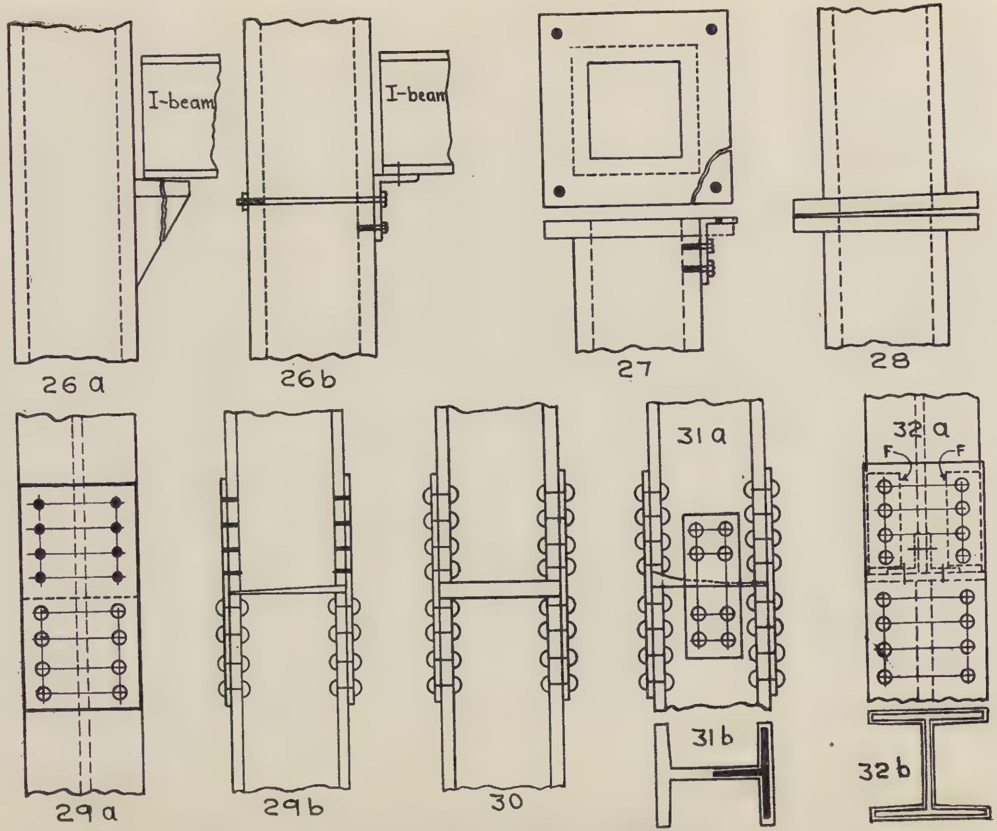
Steel columns usually come in two story lengths. This gives added stiffness and saves some field work. Cast iron columns are generally one story long in order to avoid cold shuts in castings. A longer column will also be more liable to be rejected due to defects near either end or near the centre.

CAST IRON COLUMNS are tested by tapping with a hammer just as in the case of cast iron bases. The most common defects found in cast iron columns are as follows:

1. **Eccentricity.** In casting the column, the core has shifted. This makes the column heavier on one side and lighter on the other. Eccentricity is easily detected by drilling several ⅜ inch test holes and by measuring the thickness of the column at several points. All closed cast iron columns must have test holes as required by the Code. These test holes are drilled in the shop, generally about three in number, and about two feet from the bottom flange. The Building Department has the right to demand extra test holes to be drilled in columns or bases at doubtful points.

The eccentricity can be easily detected in a round column without test holes, by causing such column to be rolled on top of two smooth edges slightly sloping downward. These may be two steel beams laid nearly horizontally. With eccentric columns the rolling is irregular. If the column has a tendency to settle along a certain side, drill a test hole in the part exactly opposite and measure the thickness of the metal. This will give the thickness of the lighter part of the column.

The Code prescribes that in case of eccentric columns whenever the core has shifted more than one-fourth the thickness of the shell, the strength shall be computed assuming the thickness of the metal all around, equal to the thickness of the thinnest part, and the column shall be condemned if this computation shows the strength to be less than required by the Code.



Defects in Cast Iron and Steel Columns Connections.

2. **Cracked Columns. Deceitful and Correct Remedies.** Columns are often cracked in cooling or in shipping. Dishonest foundry men will sometimes fill in the cracks with paint. Cracked columns are discovered by sounding with a hammer.

Some times part of a flange or lug may be broken off in setting, as in Fig. 26a. Such defects may be remedied by sawing off the broken lug at the root, and by providing a steel knee angle in place of the original lug. This angle may be bolted to the body of the column by means of ¾ in. tap bolts, and one or two through bolts as shown in Fig. 26b, will prevent the steel angle from pulling away from the column.

In the case of column to column connections where cast iron columns are used, the Building Code requires not less than four ¾ in. bolts in each column connection. Where a flange is chipped off so that a portion containing a bolt hole is missing, and when no injury to the main column body has been caused, a heavy steel angle about 6x4x½ in. can be bolted with two ¾ in. tap bolts as in Fig. 27. The steel angle has a 13/16 hole in the outstanding leg for a ¾ in. bolt.

One more instance of cracked columns will be mentioned. A cast iron column was being lowered in the cellar, in order to rest it on top of a cast iron base. During the lowering of the column, the cog that controlled the drum of a hand derrick slipped out, and let the column strike the base a powerful blow. The flange of the column broke. Where such things are liable to happen, both column and base should be carefully inspected for cracks, by striking a few good blows with a sledge hammer.

3. **Honeycomb.** Columns that are badly honeycombed and all columns that have blowholes or other imperfections which reduce the cross-section of the column at any point by more than 10% should be rejected according to the Code. Dishonest foundrymen will sometimes fill in the column in such spots with molten lead. This is a very low and dangerous practice and cannot be sufficiently condemned. Careful tapping with a hammer will generally locate such spots by a difference in the sound.

4. **Sand Holes** are often bored, tapped and plugged with a headless steel bolt, which is left in the column. In many cases a piece of wrought iron is heated to a white heat and hammered over or into the sand hole. This is more commonly met with in cast iron bases. Sandholes and blowholes give a dull sound on tapping. Test holes should be drilled in doubtful spots.

5. **Milling. Use of Shims.** All cast iron columns must have their ends milled to bear and at right angles to the length of the column. Where this is not the case, shims should be used. Good specifications prohibit the use of shims, because shims concentrate the load at points, and occasionally crack the flange; but mostly because shims cause eccentric loading on the column below.

In a 12 story structure where only cast iron columns were used the specifications prohibited the use of shims. As the workmanship of the foundry was inferior, many columns could not be made plumb, due to the incorrect milling, and some that were kept plumb by iron floor beams bolted to such columns, would only touch the lower column on edge. See Fig. 28. This brought the whole load eccentrically on the lower column, causing excessive bending. Wedges were ordered to be put in at the high end, although contrary to specifications, but just to cause less eccentricity at the low end, and to make the load of the column above come nearer the centre of the lower column.

Where shims have to be used, they should not be nails, but steel plates or wedges. Steel plates 1/16 in. thick, four to six inches wide and of a length nearly equal to the diameter of the flange may be found suitable. Two or more such plates can be used together, one on top of the other, when necessary.

6. **Painting.** In good jobs the ends of cast iron columns after being milled, are treated with white lead and tallow. Otherwise all cast iron work must be delivered unpainted and must not be painted until inspected and approved by the Building Department. The inspector may order any cast iron work that was painted before approval, to be washed with kerosene, benzine or other dissolvent, for the purpose of removing the paint and uncovering the metal for inspection. After inspection, all iron work must receive at least one field coat. This is usually done in cast iron work after the columns are in place.

7. **Bolting.** Cast iron structures are generally inferior to steel structures mainly on account of having bolted connections. These connections do not possess the rigidity offered by riveted connections in steel work. As it is, however, unusual attention must be given to bolting in cast iron work.

All bolts must be of sufficient length to grip the full dept of the nut.

All bolts must be tight.

All bolts in column flanges must be ¾ in. diameter; and no bolts should be less than ¾ in. diameter when used in 13/16 in. holes.

No bolts should be omitted. Where holes do not match, a drift pin cannot be used as it may crack the cast iron. The hole should, therefore, be reamed out with a hand or a compressed air reamer or drill.

8. **Plumbing Up.** All columns should be made plumb and kept plumb by means of guy ropes with turn-buckles. These guy ropes running transversely from wall columns to interior columns, will also strengthen the structure during construction against wind pressure.

As an additional measure of precaution, the brick walls and floor arches should be carried up as quickly as possible. The guy ropes may be removed from floors where the masonry has been completed, and has set sufficiently.

STEEL COLUMNS.

1. **Lengths.** These are generally made in two and three story lengths. The three story columns are mostly used as the last sections near the top of the buildings. While such columns save some splices and field riveting and give a stronger job, they would be too heavy and too difficult to handle, if used in the lower stories.

2. **Temporary Bolts.** All steel columns are set approximately plumb; temporary bolts are next provided in the column splices. It is customary to demand not less than 50% of temporary bolts in connections which are to be riveted. These temporary bolts:

(1) Increase the resistance of the structure against wind pressure and are therefore more necessary in long columns and in tall, narrow structures.

(2) They make field connections to match and to come fair before riveting.

3. **Erection and Temporary Bracing.** Whenever practicable columns are erected in panels of four, and the beams in between are set in place to tie them together. In addition columns in outside panels are tied with diagonal steel ropes to the first or second floor immediately below. These ropes are provided with turn-buckles and are used to draw the columns into a plumb position. Such ropes greatly increase the resistance of the structure against wind pressure. For this reason more diagonal braces are required in taller and narrower buildings.

The columns are next made plumb and then the splices are riveted. To insure plenty of work on hand for the riveters, the iron superintendent will often have several splices temporarily bolted, along any vertical line of columns, thus

keeping the erectors considerably ahead of the riveters. When the number of unriveted or open splices becomes too large the structure may be endangered through lack of rigidity; in fact it may be blown out of plumb. To avoid such accidents it is customary to allow not more than three open splices along any column, in structures that are well tied with longitudinal steel ropes.

4. **Riveting.** Riveting splices may proceed from any column; some engineers, however, will start with the outside columns. Column splices are usually riveted in all tall buildings, while beam connections are either bolted or riveted.

It is interesting to note, that there is nothing in the building code compelling an architect to specify the use of rivets, when he desires to use bolts, except that about 20% more bolts are required for field work by making the allowable unit stresses for bolts smaller than for rivets. Now bolting column splices is half as expensive as riveting, and in the case of a new twelve story loft all column splices as well as beam connections were bolted. The iron contractor had his choice between bolting and riveting; hence he preferred bolting which was much cheaper. This however is not good practice and the usual specifications should state that all column splices as well as beam connections within three feet from a column should be riveted; other connections may be either bolted or riveted.

In a twelve story building intended to be used as a printing establishment, all connections have been riveted.

5. **Splice Plates.** Before riveting column splices, it is very important that the splice plates should be straight and that all holes should match. Bent splices prevent the formation of tight rivets. This is due to a spring action in the steel plate when bent. Plates slightly bent through handling, or while in transit, may be straightened out before riveting by means of a few blows with a heavy sledge hammer.

6. **Milling.** According to the Building Code all columns must be milled at their ends at right angles to their axes. Milling can be performed with wonderful accuracy and up to 1/500 of an inch if necessary. Where milling is not carefully performed, columns will bear on one edge only (see Fig. 29), causing dangerous eccentric loads and additional bending in the columns below.

7. **Incorrect Lengths and Remedies for Same.** Another case of a similar nature results where a column is cut too short (see Fig. 30), or where the field holes in the splice plates are punched too high. In such cases the upper column

will not bear at all upon the lower and clear daylight may be seen between the two columns, while all the load is carried by the splices.

These conditions may be remedied in one of the following ways: (a) By shiming or wedging. Wedges of proper size may be driven in between the column ends. This, however, tends to concentrate the load at points instead of distributing it uniformly. Wedges should not be used in good work. (b) By providing the splice plates with sufficient rivets to safely carry the load, or by providing additional splice plates, as in Fig. 31. In this case first find from the Table of Loads or the Column Schedule for the particular structure under consideration, the load carried by the upper column. Then find out if the upper column bears partly on the lower column. For every square inch of full bearing allow 16,000 lbs. as per Building Code. The balance of the load must be taken up by additional rivets in shear. For instance: let the load on the upper column in Fig. 31a be 72 tons. By sticking the blade of a penknife in between the ends of the two columns it is found that the upper column bears only on the part shown in black in Fig. 31b. Let us say that this area is about 4 square inches. This will transmit in bearing at 16,000 lbs. per sq. in. $4\times16,000$ lbs., or 32 tons. The 16 rivets in the upper half of the splice will carry $16\times2=32$ tons in shear. We have so far accounted for 64 tons. Additional means must be provided for the remaining 8 tons up to 72 tons. Two ⅜ in. plates may be used, one on each side of the splice as shown on the inside of the column in Fig. 31a. This will place the new rivets in double shear, and carry easily the 8 additional tons. Instead of using inside fish plates as in this case, extra rivets may be provided in the original splice plates, and where the loads are heavy additional one inch diam. rivets may be used in the splice plates instead of ¾ in. rivets. (c) Where the columns are correctly milled and the holes in splice plates have been punched too high, the upper column may be lowered until it fully bears on top of the lower column. The operation requires careful manipulation. (d) When the gap between the two columns is uniform in width, a rectangular steel plate of sufficient thickness to fill the opening may be driven in between the two column ends, in such manner as to make both the upper and the lower column to come in full contact with this plate, as shown in Fig. 32a.

8. **Butt Plates.** Such plates are generally used in all cases where the column section changes, and are known as butt plates or bed plates. Following are common defects in butt plates:

a. When the plates are shipped loose, some may get lost on the way, and shims may be substituted in order not to delay the erection work; or else the plates are left out. Both these methods should be condemned.

b. The plates may get mixed up. In this way plates slightly larger than necessary are driven with quite some trouble in some splices, while plates too small to cover the lower column section are used in other places, where the larger butt plates should have been used.

Butt plates should cover the lower column completely and should extend in between splice plates from splice to splice. In good jobs butt plates must not run shorter than 1/16 inch at either end. When the clearance between the edge of the butt plate and the splice plate is larger than 1/16 inch, the butt plate should be pulled out and replaced.

Most of the above defects can be easily avoided, and better work can be obtained in a shorter time, when the butt plates are shipped to the job bolted to the lower end of the column. This is shown in Fig. 32. The bottom view represents (Fig. 32b) the cross section of two H-Columns, the upper column being of smaller section than the lower one. Fig. 32a shows a butt plate between the two columns and two angles riveted to the web of the upper column and to the butt plate.

9. **Filler Plates.** When the depth of the upper column is less than the depth of the lower column, the difference in depth is made up by providing packing known as filler plates. These filler plates make possible tight riveting; they also stiffen the column splice, and when they are fairly thick and well riveted to the upper column, the fillers may be milled even on the bottom with the main column section and they will help distributing the load of the upper column upon the top of the lower column. Fig. 32a. shows two fillers FF between the upper column and the splice plate. There are four of these fillers in this splice, and the fillers do not bear upon the bed plate.

In good work instead of two such fillers like FF only one wide filler taking in the whole width of the upper column is used. Furthermore these fillers are milled to bear and they extend above the splice plate for about three inches, or enough to have the fillers riveted in the shop with a couple of rivets to the upper column. Where this is not done, the fillers are shipped bolted to the upper column, and very often they get lost on the way and are left out. This is bad practice and should not be allowed.

CHAPTER XII.

Beams and Girders.

USES. Beams and girders are used in steel structures in a great variety of forms for many purposes. We may distinguish several classes of beams:

(a) **Wall Beams.** These are beams carrying walls and are usually referred to as wall beams or wall girders. They may be single beams or Bethlehem H. sections, or they may be standard beams provided with a plate on top or on bottom to support the masonry. Many wall beams are made of double standard beams with separators in between them and bolted together. In some other cases plain built up girders or even box girders may be used to support brick walls.

(b) **Floor Beams.** These are used to carry floor arches and they usually frame either in between columns or in between other beams.

(c) **Tie Beams** are used mainly for the purpose of tieing in the columns to one another and to the walls. These beams generally carry no load and are often replaced by channels, angles, rods or plates.

Very often one beam belongs in the same time to two or more of these groups, and its connections at each end must be designed accordingly.

(d) **Struts.** All beams stiffen the structure. In tall buildings it is sometimes found necessary to figure some of the floor beams in between columns as struts. Such beams are made sufficiently heavy to take up wind pressure in addition to floor loads.

CONNECTIONS. Beam connections are generally figured for shear and for bearing; in special cases the connections are investigated for their resistance to bending caused by eccentricity, for crippling or tearing across in between rivets and for resistance to stresses caused by wind pressure. In order to reduce costs, it is customary to use the same type of a connection throughout a whole structure whenever possible. This establishes then a typical or standard set of connections. Some structural plants have their own standard connections and they employ same on all jobs, whenever possible. Any connection which is not standard should be drawn to a larger scale and filed with the plans for approval. The standard con-

nections for steel beams framing into steel columns or girders are different from the standard connections of beams framing into cast iron columns.

Standard Connections for Steel Beams to Steel Columns and Girders. While there is no such thing as a universal standard, the variations between different standard connections are small. The connections adopted by the Carnegie Steel Co. are in common use in this country and have been selected by the author as an illustration of standard connections.

These connections are figured allowing a working unit stress of 20,000 lbs. per square inch for bearing, and 10,000 lbs. per square inch for shear. In most cases it will be found that the number of rivets provided is ample. There are rare instances, however, where the standard connections are not sufficiently strong, as in the case of beams on short spans loaded to their full capacity. The following table gives the minimum spans of I-Beams and Channels for which standard connection angles may be safely used, with the beams loaded to their full capacity. The same connections may be used for all greater spans. For spans shorter than given in this table, and for beams fully loaded, additional rivets may be found necessary.

TABLE OF MINIMUM SPANS.

For which standard connections may be safely used with beams uniformly loaded to their full capacity, figured with an allowable fibre stress of 16,000 lbs. per sq. in. in the beams.

Shape	Span in feet	Shape	Span in feet	Shape	Span in feet
3 in. I 5.5 lbs.	1.7	8 in. I 18 lbs.	6.2	15. in. I 80 lbs.	14.5
3 in. I 7.5 lbs.	1.2	8 in. I 25.25 lbs.	5.1	15 in. I 100 lbs.	18.1
4 in. I 7.5 lbs.	2.8	9 in. I 21.0 lbs.	7.7	18 in. I 55 lbs.	13.7
4 in. I 10.5 lbs.	2.2	9 in. I 35.0 lbs.	7.5	18 in. I 70 lbs.	12.4
5 in. I 9.75 lbs.	4.1	10 in. I 25.0 lbs.	9.3	20 in. I 65 lbs.	13.9
5 in. I 14.75 lbs.	3.7	10 in. I 40.0 lbs.	9.6	20 in. I 80 lbs.	14.8
6 in. I 12.25 lbs.	5.6	12 in. I 31.5 lbs.	7.3	20 in. I 100 lbs.	16.7
6 in. I 17.25 lbs.	5.3	12 in. I 40 lbs.	8.2	24 in. I 80 lbs.	17.7
7 in. I 15.00 lbs.	4.9	15 in. I 42 lbs.	10.2	24 in I 100 lbs.	17.1
7 in. I 20 lbs.	3.6	15 in. I 60 lbs.	10.8		

Shape	Span in feet	Shape	Span in feet
3 in. Channel 4.0 lbs.	1.1	8 in. Channel 11.25 lbs.	4.4
3 in. Channel 6.0 lbs.	0.8	8 in. Channel 21.25 lbs.	3 6
4 in. Channel 5.25 lbs.	1.9	9 in. Channel 13.25 lbs.	5.4
4 in. Channel 7.25 lbs.	1.4	9 in. Channel 25.00 lbs.	4.7
5 in. Channel 6.5 lbs.	2.8	10 in. Channel 15.0 lbs.	6 6
5 in. Channel 11.5 lbs.	2.5	10 in. Channel 35.0 lbs.	7.0
6 in. Channel 8.0 lbs.	3.9	12 in. Channel 20.5 lbs.	5.4
6 in. Channel 15 5 lbs.	3.9	12 in. Channel 40.0 lbs.	6 6
7 in. Channel 9.75 lbs.	3.4	15 in. Channel 33.0 lbs.	7.4
7 in. Channel 19.75 lbs.	2.9	15 in. Channel 55.0 lbs.	8.7

The minimum spans given in the above table may be found approximately by the following rules:

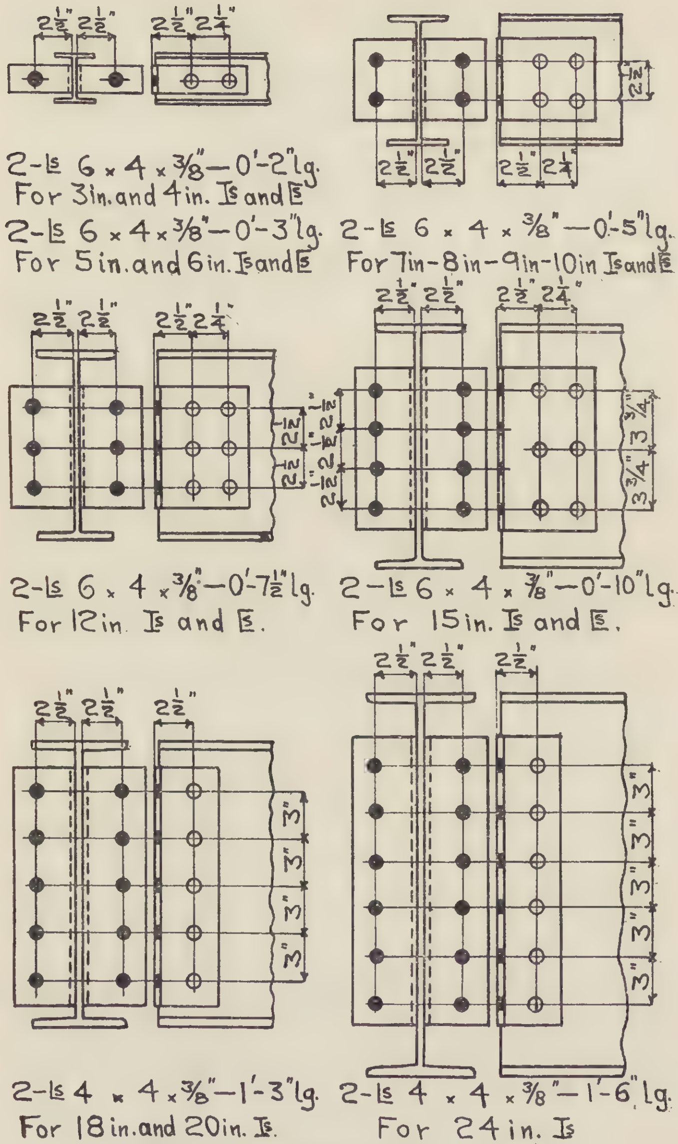


Fig. 33.—Standard Connections for Steel.
All shop rivets ¾ in. diam.
All holes for field rivets 13-16 in. diam.

Minimum span in feet for I-Beams = ¾ × depth of beam in inches.

Minimum span in feet for Channels = ½ × depth of channel in inches.

Standard Connections for Steel Beams to Cast Iron Columns. Cast iron is weak in bending. It it therefore necessary that heavy lugs should be used under the seat of each beam. It is equally important to see that the end of the beam rests on the seat.

Following is a set of standard connections for beams framing into cast iron columns. These connections are in common use.

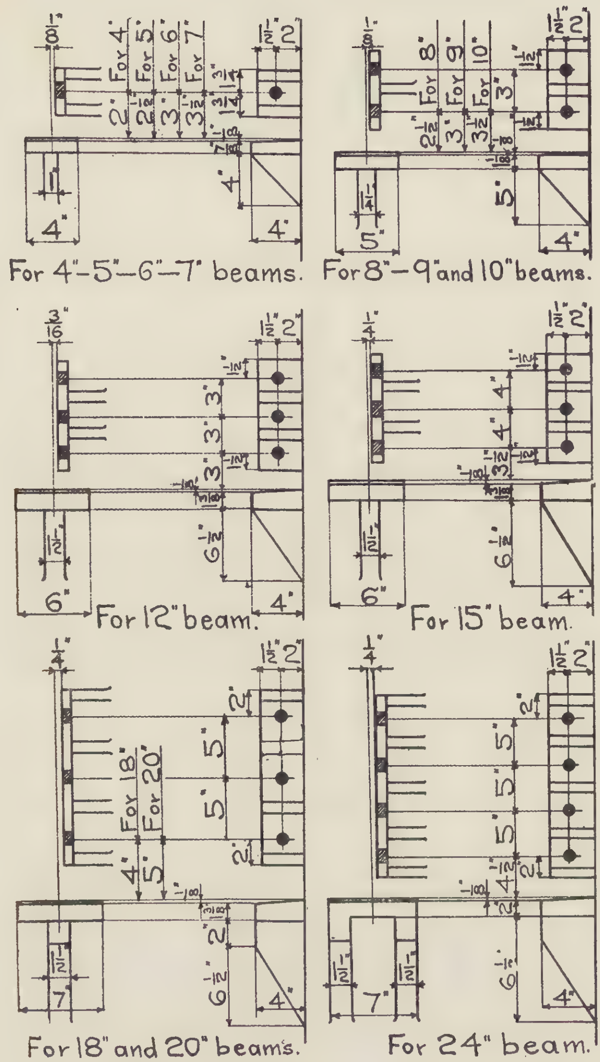


Fig. 34.—Standard Beam Connections to Cast Iron Columns.
All lugs are to be 1 in. thick except where otherwise noted.
All holes drilled for ¾ in. diam. bolts.

CHAPTER XIII.

Sidewalk Beams.

1. **Uses.** These beams are intented to support the sidewalk over the vault area, as well as the metal door frames used for stairwells and ash-hoists openings. In addition sidewalk beams will also brace the top of the street retaining walls against the steel columns of the main structure. Guide rails of ash-hoists and other sidewalk elevators are often kept in line by the sidewalk beams.

2. **Loading.** All sidewalk framing must be designed to carry not less than 300 lbs. live load per square foot. By using roughly 400 lbs. per sq. foot for sidewalk loading, this will allow for both the dead and the live load. While this loading is seldom realized in practice, it is nevertheless essential for safety, when we consider the fact that heavy merchandise boxes are often dumped on edge from express wagons upon the sidewalk. This also shows why considerable care must be given to all connections of sidewalk beams.

It often happens that such beams are only at first put in an approximately correct position and then bolted temporarily, and the erector may or may not have the intention to go over these connections before the job is finished. The masons and floor arch people will often cover the top and sides of some of the connections before all the bolts have been put in. Only constant inspection will secure good work.

3. **Framing.** Sidewalk beams are usually wall bearing at one end and bolted to the main steel work at the other end. When these beams are not riveted to the main structure, they may be removed whenever necessary to allow for the passage of boilers or elevator machinery from the street into the cellar. Instead of this, several beams near the centre of the first tier may be left temporarily bolted, without floor arches in between and covered with planks, until all necessary boilers and machinery has been lowered into the cellar.

At this time it often happens that the steel contractor will refuse to bolt any such beams for the second time, while mechanics who have temporarily removed them to lower their machinery or boilers will often not put all the bolts back and will seldom make them tight. Connections of such interior beams can be inspected more readily than connections in the front of the building, as the latter are often covered with

brick work before being inspected. Having in view the importance of good permanent connections in case of all sidewalk beams, it is reasonable to specify and insist upon having sidewalk beams riveted to the columns, whenever possible. While the Code gives no specific information on this point, whenever the approved plans specify that all column connections must be riveted, this provision should be enforced also in case of connections of sidewalk beams to columns. Connections of small framing beams in between the main sidewalk beams may be bolted.

DEFECTIVE WORK. Following are a few examples of more or less common occurrence in sidewalk framing.

1. **Incorrect Elevation.** The beams may be set too high or too low. In one instance the sidewalk had an easy continuous slope along the whole fifty feet of frontage. One end of this front building line was four inches higher than the other. It happened that the surveyor did not notice this difference in elevation and he considered the building line and the curb line as being level. He started the work from the low point. Then came the iron erector and set his grillage and other members using the high end of the building line as his starting point. The result was that all the sidewalk beams were set too high and nearly all of them had to be reset. This required drilling new holes and resulted in defective connections, which had to be carefully reinforced.

2. **Slope.** All sidewalks in Manhattan must be raised from the curbstone in the proportion of 2 inches in 10 feet, under the penalty of $10 (Art. III., Sec. 118, City Ordinances). This slope is usually formed by lowering the outer ends of the steel beams in the same proportion; when necessary, the same slope may be obtained by using an extra fill in the sidewalk material and sloping its top surface as required while the steel beams are set level. This, however, could not be done when the first tier beams are set too high.

3. **Wrong Setting.** In some cases several sidewalk beams were set upside down. In the shop all tie-rod holes were punched 3 in. from the top. Under the conditions, some tie-rod holes came 3 in. from the bottom. All the beams that were upside down had to be unbolted and turned in their proper position, thus bringing all tie rod holes in a level line 3 in. from the top. Otherwise new tie rod holes would have to be drilled in those beams.

4. **Anchors and Plates.** The outer end of most sidewalk beams bear on the retaining walls. At this end steel templates and ¾ in. government anchors or other good anchors

should be provided. These anchors are sometimes left out where the beams have considerable bearing and on a short span. This however is against the Code and against good practice and is not met with in first class work. Where there is a possibility that government or other loose anchors may be stolen or omitted, architects may specify bolted or riveted anchors consisting of two knee angles attached to the end of each beam.

5. **Vault Framing.** Sidewalk beams are often used to support a vault roof over an area. According to Art. VI., Section 186, of City Ordinances, every description of opening below the surface of the street in front of any shop, store, house or other building, if covered over, shall be considered and held to be a vault or cistern within the meaning of said article. A grating or open iron work used to connect an entrance to the sidewalk by spanning over an area is not a vault; also openings used exclusively as places for descending to the cellar floor of any building or buildings by means of steps must not be considered as vaults. (Art. VI., Sec. 187, City Ordinances). Also, vaults must not extend further than the line of the sidewalk or curbstone (Art. VI., Sec. 173, City Ordinances).

Before a vault is built, a permit must be secured from the Bureau of Highways. Such permits are granted only after the payment to the City of a sum varying between 30 cts. and $2 per sq. ft. of vault area, depending upon location. But permits for vaults in public highways are in the nature of revocable private easements which can be fully enjoyed until revoked by and at the pleasure of the Board of Aldermen.

It sometimes happens that vaults are put up without a permit. This is a violation which may be prosecuted and a penalty of $100 or more may be enforced. In addition a permit may be refused, in which case the whole vault must be taken down. Cases of erecting vaults without a permit are reported to the Bureau of Buildings by either construction or iron inspectors; thence the cases are usually referred to the Bureau of Highways for prosecution.

6. **Old Vaults.** It often happens that old buildings having vaults are demolished to make room for new structures. It is reasonably presumed that any vault which has existed for a number of years has been originally constructed with the consent of the municipal authorities. It is therefore not necessary to ask for a new permit or to pay a new vault fee as long as the old vault is not demolished. However, when an old vault is taken down and reconstructed a new permit must be secured, as demolishing a vault will automatically

discontinue the original permit. This causes old vaults to be carefully shored and incorporated within new vault framing when larger vaults are desired. Where this is the case the iron work of the old vault must be carefully inspected as to quality, strength and connections, considering in addition to the old load carried by the vault framing in place any extra load which may be thrown upon the old iron beams by means of connections of the new framing to the old beams in place.

7. **Hoist Guides.** Channel beams are often used in vault framing to keep in line the guides of the ash hoists or other sidewalk freight elevators. When I-beams are used around elevator shafts or around openings it is sometimes necessary to cut through one or both flanges of such beams to make room for the elevator guide rails. This arrangement will often weaken the sidewalk beam to an extent requiring reinforcement. The sidewalk beam may be reinforced by means of one or more plates well bolted to the top or sides of the beam. When the guide rail is heavy and bears at its lower end solidly like a strut, the beam may be reinforced by means of a knee angle placed under the beam and bolted to the guide rail.

CHAPTER XIV.

Erection and Inspection of Stairways

1. **Inspection.** Perhaps no part of a structure requires more attention from the part of the inspector or superintendent than the stairways. Any other part of the steel structure receives a large proportion of its final allowable load in the form of floor or wall dead loads, and the failure of such a beam will most likely be noticed long before it actually takes place, through the increased deflection or through cracks in the plastered ceiling below it. Furthermore such a failure may be of local importance, and the resulting damages might affect a small portion of a single floor.

On the other hand, consider what happens in the case of outside stairways. Their builder is paid after his work is completed and before these stairways have been made to carry practically any load except the dead load of the metal itself, which amounts usually to only one-tenth of the total load. In this way there is nothing to show by actual loading whether the stairway anchorage and connections could stand much more than the negligible weight of the iron itself. Furthermore, the effect of wind pressure will be a maximum when the stairs are fully loaded, and should the wind braces and other anchors fail to keep the stairs in position under these conditions, which may exist during a fire panic, the results would be nothing short of a calamity. For these reasons much attention must be paid to all details of the stairwork, and especially to the means used to secure such stairways to the main structure in such a manner as to exclude any remote possibility of a failure, when such stairs are fully loaded.

DEFINITIONS OF TERMS.

The various main parts of an iron stairway are as follows:

Stair Stringers. These are perhaps the most prominent part of the stairway. They are the inclined pieces or bars set edgewise as a support for the steps, and are generally made of a steel plate about eight to ten inches wide, set on edge, and reinforced along both edges by means of 1¼x1¼ inch angle irons. In a patented system the stair stringer and the reinforcing angle irons are replaced by a one-piece stringer, having the edges reinforced by buckling same in a rolling machine.

Stair stringers for exterior stairways should be not less than ¼ inch in thickness. Stair stringers for interior stairways should be not less than 3/16 inch in thickness.

Bolted to the stringers are the **Carriers,** also called shelf-angles. The carriers carry the steps of the stairway. Carriers are usually made of short angle irons bolted to the stair stringers with at least two bolts in each angle.

Steps usually consist of risers and treads. A **Riser** is an upright plate or board forming the vertical face of a step.

Treads are the horizontal boards or plates on which the feet tread.

The Rise of a stair is the vertical distance from the top of one step to the top of the next step. The total rise is the distance from one finished floor to the next finished floor.

The Run of a stair is the horizontal distance from the face of one riser to the face of the next riser. Treads are generally about 1½ inches wider than the run, on account of **the Nosing,** or the overlaying projection of the tread beyond the face of the riser.

The Baluster is a fence-like arrangement supported by the stair stringers and preventing people from falling over the edges of the stairs. The baluster consists of a **Hand Rail** at its upper part, and of a number of **Standards** or filling-in bars, which run vertically between the stringer and the hand-rail every few inches apart. The standards may be either flat, round or square steel bars.

From distance to distance, and especially at turning points, heavy square or round **Newel Posts** are provided to reinforce the balusters.

Winders are steps wider near the outer edge and narrower near the centre of the stairway. They are essential elements in some systems of spiral stairways. Winders are not allowed in public stairways in office or loft buildings.

Exterior lines of stairways are sometimes continued to the roof of the building by means of usual stringers, steps and balconies. In other cases, a line of stairs may be brought up only to the top floor. Such stairways are sometimes continued to the roof by means of a vertical iron ladder fastened to the wall and curved over the parapet wall of the building. From the shape of their curved portions, such ladders are known as **Goose-Neck Ladders.** In place of iron steps these ladders are provided about every twelve inches in height with a round iron bar known as a **Rung.**

Interior lines of stairways are generally continued to the roof by a stair of the same construction as the main body of

the stairway, and an enclosure provided with a full size door is usually provided at the upper end of the stairway. Such an enclosure is referred to as a **Bulkhead.**

Still in other cases the main stairway stops at the top floor, and the communication to the roof is made by means of a ladder running from any point on the top floor to a rectangular opening in the main roof. Such an opening is usually provided with a movable rain-cover and is known as a **Scuttle.**

The interior stairways have their stringers supported on the brick walls or connected to columns or to the steel floor beams of the main steel framing by means of round rods or **Hangers.**

Exterior stairways have their stringers supported on upright posts erected for the purpose. Such stringers are anchored to the main building by means of anchors bolted to floor beams or columns at the various floors. Balconies of exterior stairways are sometimes supported on **Brackets.** A bracket is shaped like a right-angled triangle, one short side of which is applied to the wall vertically and is securely anchored to the wall.

COMMON DEFECTS. Following are some of the common defects found in iron stairways. Some of these defects are found in both interior and exterior stairs, others in exterior stairs only.

1. **Unpainted Iron.** There is no reason why unpainted iron work should be erected. Certain parts, like those resting against walls, become inaccesible after erection. Furthermore, the material used in making the treads and risers for interior stairs is usually light steel plate, and this will often become seriously weakened by rust when exposed unpainted in the field. The inspector shall see that all iron work, including newel posts, treads and platforms shall be painted one coat of good paint before erection. Violations filed in such cases should not be recommended for dismissal until all bolted connections have been loosened up and all stringers have been sufficiently displaced to allow of proper painting.

2. **Incomplete Field Painting.** Exterior stairways are often painted two coats after erection. In several instances it was found that where stringers rested alongside the face of a wall the painters made no effort to paint the surface of the stringer facing the wall. This, however, can be performed in most cases, especially when a row of windows happen to open along the stairway, or when the stringer is about four inches from the wall.

3. **Short Stringers.** In good work a stringer resting on a brick wall will be provided with at least six inches of bearing. Four inches of bearing is common bad practice, and in some cases the stringers were made to rest on a lump of plaster.

All stringers having less than six inches bearing may be extended into the wall by bolting to the stringer a steel plate of the same depth as the stringer, and by using two or three one-half inch bolts in such connection. A 4x4 angle or a piece of a channel properly bolted may be used in place of the steel plate.

4. **Cutting Stringers.** It sometimes happens that a stringer is laid out wrong in the shop, and when erected it may project too far above the floor level or opposite a doorway. This projecting part is sometimes cut out, without reinforcing the remainder of the stringer. Although highly unsafe, such work is rather common.

5. **Light Weight.** Stringer plates, upright struts in exterior stairways, and very often treads, risers, platforms and newel posts are found to be light in weight. Stringers for exterior stairways are not allowed to be less than ¼-inch in thickness; interior stair stringers must not be less than 3/16-inch thick. This difference is due to the fact that the exterior stringers are more exposed to corrosion.

6. **Width of Stairs.** Exterior and interior stairways should be at least three feet four inches wide in clear. In some instances stairs three feet wide or less have been allowed, when such stairs are used for private purposes and are not the public stairways of the building.

7. **Winders** are allowed only in private stairways.

8. **Head Room.** A head room of about six feet in clear would be the minimum to be used in stairways or fire passages. On account of intricate arrangements in some buildings, the head room in fire passages on the first floor are sometimes found to be wanting in height and contrary to the approved plans.

9. **Hangers.** Interior stair stringers are often hung unto the main floor beams by means of flat or round steel hangers. Round bars three-quarter inches in diameter form excellent hangers. Such rods should be well bent at their upper end to catch the flange of the floor beam.

Some hangers may be bent cold or injured during bending or heating. For this reason the bent portion of each hanger should be carefully examined. Any flaw or serious check in the bend should be sufficient cause for rejection.

Similarly all hangers that are too long or too short, or of less diameter or thickness than required in the approved plans, should be either fixed or rejected. Hangers that are too long may be packed up with a piece of pipe or with washers. Hangers that are too short may be elongated by attaching to them a sleeve. Short hangers, however, are usually replaced.

The following common defects are mostly met with in exterior stairways:

10. **Defective Anchorage.** Anchors required to pass through a brick wall and to be provided with a plate or washer on the inside face of the wall are often replaced by expansion bolts or by plain bolts driven a few inches into the wall.

In good work the anchors for exterior stairways are made of heavy angle irons bolted in the proper place to the main beams or columns by means of two or more ¾-inch bolts before any brick work is placed around such anchors.

11. **Omitting Braces.** In most stairways twelve stories and over, knee braces under platforms and other extra braces may be required. With careless supervision such braces are often omitted. The same applies to base stones and steel plates that may be required to be provided under each stair upright.

12. **Defective Uprights.** All uprights in an outside stairway are acting as columns. They should therefore be milled at both ends in order to bear properly. Where this is not done the uprights will not line up and this may cause undue bending for some of the lower floor uprights. Whenever the uprights are out of line and do not bear at splices, extra knee braces and stronger splice plates with more bolts in them may be found necessary.

13. **Defective Splices.** Six ¾-inch bolts in each upright end at the splice will be found sufficient for all purposes for stairs twelve to sixteen stories in height, when the uprights bear at the splice and the stair is well anchored to the main structure. Where this is not the case, additional splice plates and extra bolts should be provided.

14. **Shaky Balusters** are of common occurrence. The balusters may have to stand much pushing in the case of a fire panic. To test the rigidity of balusters just get hold of the hand rail and shake it. All balusters thus found to lack rigidity should be stiffened by providing vertical brackets on the outside of the stairway, between the hand rails and the stringers. Where a stringer of one stairway is close to the

hand-rail of another, the baluster may be stiffened by providing a short bolted piece between the stringer and the hand rail. This is often done in interior stairways.

15. **Uprights of unlawful length** are often used in the lower part of an iron stairway. The maximum unsupported length for uprights made of various angle sizes is given in table XVII. Whenever an upright exceeds this length additional knee braces or braces from upright to upright should be provided.

OUTSIDE FIRE ESCAPES.

Buildings required to be provided with fire-escapes are enumerated in Section 103 of the Building Code, as given in Chapter XVII. of this book.

The Bureau of Buildings has the supervision of the safety of construction of all fire escapes. Plans must be filed with the Bureau of Buildings for all fire-escapes.

Fire-escapes in tenements are also inspected by tenement house inspectors.

The Fire Prevention Bureau issues regulations for outside fire escapes in all buildings except tenements, and has permanent charge of their inspection and maintenance.

Following are the **REGULATIONS FOR THE CONSTRUCTION OF OUTSIDE FIRE-ESCAPES,** as promulgated by the Bureau of Fire Prevention and in effect since December 14, 1911.

Unless otherwise approved by the Fire Commissioner in writing, outside fire-escapes shall be arranged and constructed as follows:

1. **Location.** Iron balconies at least four feet wide shall be located as directed by the Fire Commissioner. They shall communicate one with the other by means of stairs and with the ground by either stairs or drop ladders as may be ordered. The balconies must be of sufficient length to comply with all the requirements of these regulations.

2. **Balconies.** The balconies shall have a landing not less than twenty-four inches square at the head of each stairway. Except in cases where the stairways reach and leave the balconies at the ends, there shall be a passageway at the side of the stairs not less than fourteen inches wide in every part. The stairway opening in each platform shall be of a size sufficient to provide clear headway, and shall

be enclosed on the long side by a three-quarter-inch rail, well braced.

3. **Floors of Balconies.** The floors of balconies shall be of wrought iron or steel slats not less than one and a half inches by three-eighths of an inch, placed not more than one and one-quarter inches apart, and well secured and riveted to iron battens one and a half inches by three-eighths of an inch, not over three feet apart and riveted at the intersection. The ends of such floor slats shall project beyond the platform frame, but shall not rest on the bottom rail. The openings for stairways in all balconies shall not be less than twenty-one inches wide and thirty-two inches long, and such openings shall have no covers of any kind. The platforms or balconies shall be constructed and erected to safely sustain in all their parts a safe load at a ratio of four to one, of not less than eighty pounds per square foot of surface.

4. **Railings.** Except in the case where stairs are at ends of balconies, the outside top rail shall extend around the entire length of the platform and shall go through the wall at each end and be properly secured by nuts and four-inch square washers at least three-eighths of an inch thick, and no top rail shall be connected at angles by cast iron. Where stairways at ends of balconies make it impossible to secure top rails to walls, such top rails must be made rigid and secure by means of inclined braces from the brackets on the outside of the railings, or other means satisfactory to the Fire Commissioner, that will offer no obstruction along the balcony. The top rail of balconies shall be one and three-quarter inches by one-half inch of wrought iron, or one and a half inch angle iron one-quarter inch thick. The bottom rails shall be one and one-half inches by three-eighths of an inch wrought iron, or one and a half inch angle iron, one-quarter inch thick, well leaded or cemented into the wall. The ends of all rails which go through the walls shall be worked out to no less than three-quarter inch bolt size for top rails, or one-half inch bolt size for bottom rails, and if constructed as separate pieces shall be properly secured to the rails with not less than two one-half inch rivets. The standards or filling-in bars shall be not less than one-half inch round or square wrought iron, well riveted to the top and bottom rails and platform frame. Such standards or filling-in bars shall be securely braced by outside brackets at suitable intervals, and shall be placed not more than six

inches from centers; the height of railings shall in no case be less than two feet nine inches.

5. **Stairways.** The stairways shall be placed at an angle of not more than sixty degrees, with steps not less than six inches in width and twenty inches in length, and with a rise of not more than nine inches; and shall be constructed and erected to fully sustain in all their parts a safe load at a ratio of four to one of not less than one hundred pounds per step, with the exception of the treads, which must safely sustain at said ratio a load of two hundred pounds. The treads shall be flat open treads, or may be constructed of flat bars, not over one and one-half inches wide, riveted to angle irons of a size not less than one and one-half inch, with the open spaces between such bars not over three-quarters of an inch wide. The strings shall be not less than three-inch channels of iron or steel, or three-eighths by four-inch bars, or two three-eighths by one and one-half inch bars properly latticed, or two one-quarter by one and one-half inch angles properly latticed, or other shape equally strong. Unless of channel or angle iron, they shall be stiffened by the use of braces properly leaded into or bolted through the wall, and also bolted through the string at a height of not less than seven feet above the floor of the balcony. They shall rest upon and be bolted to a bracket, which shall be fastened through the wall as hereinafter provided. The strings shall be securely bolted to a bracket at the top, and the steps in all cases shall be double-riveted or bolted to the strings. The stairs shall have three-quarter inch hand-rails of wrought iron, well braced.

6. **Brackets.** The brackets shall not be less than one-half inch by one and three-quarter inches wrought iron, placed edgewise, or one and three-quarter inch angle iron, one-quarter inch thick, well braced; they shall not be more than four feet apart, and shall be braced by means of not less than three-quarters of an inch square wrought iron, and shall extend two-thirds of the width of the respective balconies or brackets. The brackets shall go through the wall and be turned down three inches, or be properly secured by nuts and four-inch square washers at least three-eighths of an inch thick. On new buildings the brackets shall be set as the walls are being built. When brackets are put on buildings already erected the part going through the wall shall not be less than one inch in diameter, with screw

nuts and washers not less than five inches square and one-half inch thick. If the end going through the wall is separately constructed, it shall be properly connected to the bracket with not less than two five-eighths inch rivets staggered.

7. **Drop Ladders.** Where drop ladders are permitted instead of stairs from the lowest balcony, they shall be of sufficient length to reach from the lowest balcony or platform to a safe landing place beneath. It shall be not less than fifteen inches in width, with strings not less than one-half inch by two inches and rungs of not less than five-eighths of an inch in diameter placed not over twelve inches apart and properly riveted through the strings. Where the lowest balcony is more than fourteen feet above the ground beneath the same, a suitable landing platform shall be provided. Such platform shall be located not more than ten feet above the ground, and shall be connected with the fire-escapes above by a stairway constructed as herein required. Such platform shall be not less than four feet in length by three feet in width, and shall be provided at each end with proper railings and a drop ladder to reach the ground. Except as specified, it shall be constructed in conformity with the other provisions of these regulations.

8. **Goose-Neck Ladders.** Wherever possible, a balcony at the top story of any building shall be provided with a goose-neck ladder leading to the roof. Such goose-neck ladder shall be securely fastened to the wall of the building and to the roof, and shall be so located as to afford safe access to the roof. Such ladder shall be constructed as provided for drop ladders; the strings shall be in one piece and shall not be connected in parts by rivets and bolts; such ladders shall be arranged to rest on brackets and not on slats forming the floor of the balcony.

9. **Scuttle Ladders.** Scuttle ladders, where required, shall be constructed as above provided for stairs, except that they may be set at a steeper angle. They must be properly secured at top and bottom.

10. **Painting.** All the parts of such fire-escapes shall receive not less than two coats of paint, one in the shop and one after erection. All fire-escape balconies shall contain a plate firmly fastened to the standards or filling-in bars near the top railing, containing in plain, large, prominent, raised letters, each letter to be not less than one-half an inch in length, the following words: "Any one placing any encumbrance on this balcony will be fined ten dollars." The

lettering on such plates shall be painted with a paint of a color different from that used on the body of the plate, so that the letters will be prominent and distinct.

11. In case it may be desired, for architectural or other reasons, to vary from these requirements in the shape of construction of the brackets or railings, such changes may be submitted to the Fire Commissioner, but shall not be made until his approval has been obtained.

12. **Windows.** All windows opening on fire escapes to be approved self-closing, and to have metal frames and sashes glazed with wire glass.

CHAPTER XV.

Roofs Tanks and Tank Supports

Uses of Roof Tanks. In all tall buildings water is required for house use, for fire extinguishing, and sometimes for manufacturing purposes. All this water is generally pumped into one or more roof tanks, whence it descends through pipes in the various parts of the building.

Three kinds of tanks are generally used:

1. **House Tanks.** These supply water for drinking, wash basins, water closets, boilers, as well as for cleaning purposes. House tanks are usually made of wood. All house tanks containing over five hundred gallons must rest on steel beams. In smaller buildings the house tank also supplies all water for fire extinguishing purposes.

The Fire Underwriters reduce the fire insurance rate on those buildings equipped with special water tanks and with a system of fire extinguishing pipes, forming what is known as a sprinkler system. The sprinkler system is now compulsory, being required by law in all buildings of a certain height and with a certain number of people working above the second floor. The tanks used for the sprinkler system are known as gravity and pressure tanks.

2. **Gravity tanks** are made of wood, just like the house tanks, but are set upon a steel framing at a considerable height above the main roof, usually between fifteen and thirty-five feet. This height creates a certain required pressure in the sprinkler pipes.

3. **Pressure tanks** are used in addition with all sprinkler systems. These are iron tanks filled up two-thirds with water maintained under a constant pressure of about seventy-five pounds per square inch or more, by means of an air compressor. Pressure tanks rest on steel beams only two to three feet above the main roof and are enclosed in heated pent houses to prevent freezing.

In a twelve-story building on a lot 50x100 feet there were two pressure tanks, each containing 6600 gallons when filled up two-thirds. Then there was a 10,000-gallon gravity tank and a 6000-gallon house tank. As in all sprinkler systems, the house tank was connected with the sprinkler pipes and its contents could be used in case of fire if necessary.

LOCATION. No tank should be placed over a stair well, as it may interfere with the work of firemen in case of fire. It is a convenient arrangement in tall buildings to have the pressure tanks about two or three feet above the main roof and enclosed in a fireproof pent house, while on top of this pent house, both the house tank and the gravity tank may be placed.

Following are a few points requiring careful consideration in tank work:

1. **Elevation of Beams.** Changes in the elevation of the tank-supporting beams, contrary to approved plans, are of common occurrence. This is sometimes done by causing each steel beam under the tank to be raised upon struts or posts which may not be sufficiently braced in between to insure rigidity.

2. **Size of Beams.** Changes in the size of beams supporting the tanks are also a common and risky operation. This is sometimes done by mistake, and where lighter sizes are used there should be no excuse for such an error.

3. **Capacity of Tanks.** This is often varied without modifying the sizes of the steel beams accordingly. To avoid unsafe conditions which may arise in this manner, a convenient table is given in Part Three for the capacity of cylindrical tanks of usual diameters. The capacity of square or other tanks may be easily figured into cubic feet.

The weight of a cubic foot of water is about 62.5 pounds and one cubic foot contains 7.48 gallons.

4. **Bolting.** In all tank towers bolting must receive special consideration. The various members and gusset plates will seldom match, and reaming holes into elongated slots or drilling new holes in between old ones is very usual. This may often render a gusset plate useless, unless the same is reinforced. Where holes have been elongated more than the diameter of the bolt shank and where any part of the hole is visible after the bolt is in place, washers should be used to cover up such holes, in order to keep away rain water and also to hold the parts rigidly together through friction.

Connections near the top of the framing are likely to contain bolts of smaller diameter than required. Very often five-eighth inch bolts are used instead of three-quarter inch bolts where holes did not match. This is partly due to the difficulty of operating a reamer or a drill high up in the air. It is, however, bad practice and should not be allowed.

5. **Wind Bracing.** All exposed roof tanks are regular targets for swift winds and storms. It is therefore essential to secure rigidity in all tank towers. This is done partly by having plenty of tight bolts in all gusset plate connections and partly by using sway or X braces and tie rods. All X braces should be bolted at the middle where they cross each other, and should be well connected at each end. All tie rods used in between steel beams should be made tight, and where the beams are not too far, double nuts may be used at each end of each tie rod, to make the ties to act both in tension and compression.

6. **Anchorage.** This part of the tank tower takes the full effect of wind pressure and must be carefully inspected. Whenever anchors must go through brick or other walls, the inspector should see that this is properly done.

7. **Saddles.** Pressure tanks are generally cylindrical in shape and rest upon cast iron or steel saddles. These saddles keep the tank from rolling and should be bolted to the iron beams.

Where the tank supporting beams are not set exactly level on top, each beam should be made to get its share of the tank load by providing tight wedges or shims between the tank and the beam. Whenever possible this should be done before the tank is filled up with water.

Erection and Inspection of Iron and Steel Constructions

PART II

CHAPTER XVI.

Permit To Build

How to Obtain a Permit. It is unlawful to start building work without a permit. Anybody can obtain a permit by applying in writing to the Superintendent of Buildings for the respective borough. Permits are issued upon printed blank forms furnished free of charge by the Bureau of Buildings.

An affidavit signed by the owner must be filed with each application for a permit. This affidavit must state that the owner gives to the architect or builder the full right to erect upon the owner's lot a certain building described in the application, or to alter the owner's building in certain ways.

Plans in triplicate are also required as per Section 4 of the Building Code.

Specifications. Complete architect's specifications are not filed with the plans, with exception of the main points relating to the work, which are to be indicated as answers to a list of about fifty questions printed in the application blank. The architect may specify on the plans in the form of notes any important details that must be carried out.

For instance in steel framing plans, notes are often put on each plan giving the size of bolts or rivets to be used, the number of coats of paint, the size of tie rods, and so on. It is the duty of the inspector to see that all the specifications contained in the permit to build or given on the plans as notes, are complied with on the job. In addition all work must comply with the Building Code, which is to be considered as being above all architect's specifications, whenever such specifications do not result in securing workmanship and safety of a higher degree than that required by the Code.

Kinds of Permits. Three kinds of permits are issued by the Bureau of Buildings for construction work:

1. New Building permits, marked N. B.
2. Alteration permits, marked Alt.
3. Slip applications, marked S. A.

The last group includes all permits for minor repairs, like pushing a store front within building line, erecting hand rails, small marquises and small signs, and making changes which do not affect the main structural framing of a building.

Printed forms for each kind of permit are furnished free of charge by the Bureau of Buildings.

A permit is good for one year, after which time it expires automatically by limitation.

Approval of Plans. In the case of any plan filed for approval the Bureau of Buildings will usually take an action within five days. If the plans are found entirely satisfactory and in compliance with the law, a permit may be issued within the above time. This is often the case with simple alteration permits. With complex plans for large jobs, the plan examiner will make a list of all defects of construction, weak parts, unlawful construction, and so on. He will also ask for any further information or sketches he may find necessary to make points in the plans or application more definite. A letter is sent to the architect containing all these objections. The architect will then revise his drawings and submit an answer containing the verification of the changes or amendments to be made in the original plans. If these changes are satisfactory to the plan examiner, he recommends the case to the Superintendent for signature of approval. Then the architect is notified and the work may be started.

Following is a complete copy of a permit to build with questions and answers for a new building:

Office of the Borough President of the Borough of Manhattan in the City of New York.

THE BUREAU OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

Office: No. 220 Fourth Avenue.
S. W. Corner 18th St. and Fourth Ave.

Plan No. 208 of 1913. New Building. Received May 20th, 1913.
(Stamped)

APPLICATION FOR ERECTION OF BRICK BUILDINGS.

Application is hereby made to the Superintendent of Buildings of the City of New York, for the Borough of Manhattan, for the approval of the detailed statement of the specifications and plans herewith submitted, for the erection of the building herein described. All provisions of the law shall be complied with in the erection of said building whether specified herein or not.

(Sign here) Signature of Architect.

The City of New York.

Borough of Manhattan, May 20th, 1913.

1. State how many buildings to be erected?—One.

2. What is the exact location thereof? (State on what street or avenue, the side thereof, the number of feet from the nearest street or avenue, and the name thereof)—About 200 ft. W. of the N. W. corner 6th Ave. and W. 38th St., and known as Nos. 25-27 W. 38th St.

3. Will the building be erected on the front or rear of the lot?—Front.

4. How to be occupied?—Offices and stores. If for dwelling, state the number of families in each house—Not for dwelling.

5. Size of the lot?—118 feet front; 93 feet 3 inches rear; 98 ft. 2 in. irregular deep.

Give diagram of same.—See plans on file.

6. Size of building?—118 feet front; 93 feet 3 inches rear; 88 ft. 2 in. irregular deep.

Size of extension?—90 ft. front; 90 ft. rear; 10 ft. deep.

Number of stories in height: Main building?—12. Extension?—One.

Height from curb level to the highest point: Main building?— 148 ft. 10 in. Extension?—18 ft. 6 in.

7. What is the character of the ground: Rock, clay, sand, etc.?—Rock.

8. Will the foundation be laid on earth, rock, timber or piles?—On rock.

9. Will there be a cellar?—Yes.

10. What will be the base, stone or concrete?—Rock. If base stones, give size and thickness, and how laid. If concrete, give thickness.

11. What will be the depth of foundation walls below curb level or surface of ground?—24 ft. 8 in.

12. Of what will foundation walls be built? Brick.

13. Give thickness of foundation walls;—front 16 and 24 inches; sides 16 and 24 inches; rear 16 and 24 inches; party 24 inches.

14. Will interior supports be brick partition walls or piers, iron columns or wooden posts?—Steel columns.

Give size of same.—See steel plans.

15. If piers, give thickness of cap stones or plates...... bond stones or plates......

16. Give base course, width and thickness......

17. Will any part of front, side or rear wall, be supported on piers in cellar?—No.

Give size: Front........size of base course........
Rear .... " ....
Side .... " ....

Size of cap stones........size of bond stones........

18. Of what materials will the upper walls be constructed?—Brick.

What will be the thickness of upper walls, exclusive of ashlar, if any?

Basement; front....inches; rear 24 inches; side 24 inches; party 24 inches.

1st Story; front 20 inches; rear 24 inches; side 20 inches; party 24 inches.

2nd Story; front 20 inches; rear 20 inches; side 20 inches; party 20 inches.

3rd Story; front 16 inches; rear 16 inches; side 16 inches; party 16 inches.

4th Story; front 16 inches; rear 16 inches; side 16 inches; party 16 inches.

5th Story; front 16 inches; rear 16 inches; side 16 inches; party 16 inches.

6th Story; front 16 inches; rear 16 inches; side 16 inches; party 16 inches.

7th Story; front 16 inch; rear 16 inches; side 16 inches; party 16 inches.

Thence 12 inches to top for all walls.

19. What will be the material for the front?—Brick, stone and terra cotta.

If of stone, what kind?—Limestone. If ashlar, give thickness?—4 in. and 8 in.

20. Will flues be lined with pipe or have 8 in. of brick around the same?—12 in. of brick.

21. Will any wall be supported on iron or steel girders?—Yes. See steel plans.

Front, material ....size....weight or thickness,
Side, material ....size....weight or thickness.
Rear, material ....size....weight or thickness.
Interior, material....size....weight or thickness.

Will any wall be supported on iron or steel columns?—Yes. See steel plans.

Front, material ....size....weight or thickness,
Side, material ....size....weight or thickness.
Rear, material ....size....weight or thickness.
Interior, material....size....weight or thickness.

22. Give material of girders?—Steel. Of columns?—Steel.

Under 1st tier, size of girders.—See steel plans. Size of columns.—See steel plans.

Under 2nd tier, size of girders.—See steel plans. Size of columns.—See steel plans.

Under 3rd tier, size of girders.—See steel plans. Size of columns.—See steel plans.

Under 4th tier, size of girders.—See steel plans. Size of columns.—See steel plans.

Under 5th tier, size of girders.—See steel plans. Size of columns.—See steel plans.

Under roof tier, size of girders.—See steel plans. Size of columns.—See steel plans.

23. Give material, size and distance on centers of floor beams.—See steel plans.

First tier, material...... ; size...... ; distance on centres......

Second tier, material...... ; size...... ; distance on centres......

Third tier, material...... ; size...... ; distance on centres......

Fourth tier, material...... ; size...... ; distance on centres......

Fifth tier, material...... ; size...... ; distance on centres......

Sixth tier, material...... ; size...... ; distance on centres......

Seventh tier, material...... ; size...... ; distance on centres......

Eighth tier, material...... ; size...... ; distance on centres......

Roof tier, material...... ; size...... ; distance on centres......

Give thickness of headers......of trimmers.......

24. Specify construction of floor filling.—Concrete arch.

25. Is the building to be fireproof?—Yes.

26. Of what material will partitions be built?—Cross partitions of 3 in. plaster block; fore and aft of 3 in. plaster block.

27. Give material of skylights.—Galvanized iron; size—see plans.

28. What will be the material of roofing?—Slag.
Will roof be flat, peak or mansard?—Flat.

29. What will be the material of dumb waiter shafts?—6 in. terra cotta.

30. What will be the material of elevator shafts?—Metal and masonry.

31. What will be the material of cornices?—Metal and masonry.

32. What will be the material of bay windows?—Metal and masonry.

33. What kind of fire escape will be provided?—Outside iron stairs.

34. Will cellar be plastered?—Yes. How?—On fire-proof arches.

35. Will access to roof be by scuttle or bulkhead?—Bulkhead. If by bulkhead how constructed?—Angle iron and terra-cotta blocks.

36. With what material will walls be coped?—Vitrified tile.

37. How will building be heated?—By steam.

38. Is there any other building erected on lot or permit granted for one?

Size......; height......; feet. How occupied?......

Give distance between same and proposed building...... feet.

39. Are any buildings to be taken down?—Yes. How many?—Four.

If the building is to be occupied as a Flat, Apartment, Tenement or Lodging house, give the following particulars:

40. Is any part of building to be used as a store or for any other business purposes? If so, state for what..........

41. How many families will occupy each?
Cellar ....
Basement ....
1st floor ....
2nd floor ....
3rd floor ....
4th floor ....
5th floor ....
6th floor ....
7th floor ....

42. Height of ceilings?......

43. How basement to be occupied?...... How made water-tight?......

44. How will cellar stairs be enclosed?....

45. How is cellar to be occupied?...... How made water-tight?......

46. Will shafts be open or covered with louvre skylights full size of shafts?......Size of each shaft?......

47. Dimensions of water closet windows?...... Dimensions of windows for living rooms?......

48. Of what materials will hall partitions be constructed?......

49. Of what materials will hall floors be constructed?....

50. How will hall ceilings and soffits of stairs be plasetred?...... Halls on fireproof arches; stairs unplastered.

51. Of what material will stairways be constructed?—Iron. Give sizes of stair well holes?—4 inches.

52. If any other building on lot, give size: Front......; rear......; deep......; stories high......; how occupied ......; on front or rear of lot......; material......

How much space between it and proposed building?......

53. How will floors and sides of water closets to the height of 16 in. be made waterproof?—6 in. marble.

54. Number and location of water closets: Cellar......; 1st floor......; 2nd floor......; 3rd floor......; 4th floor ......; 5th floor......; 6th floor......; 7th floor......

55. This building will safely sustain per superficial foot upon the 1st floor 150 lbs.; upon 2nd floor 75 lbs.; upon 3rd floor 75 lbs.; upon 4th floor 75 lbs.; upon 5th floor 75 lbs.; upon 6th floor 75 lbs; upon 7th floor 75 lbs; upon 8th to 12th floors 75 lbs.; upon roof 50 lbs.

56. What is the estimated cost of each building, exclusive of lot?—$400.000.

57. What is the estimated cost of all the buildings, exclusive of lot?—$400,000.

58. Is architect to supervise the erection of building or buildings mentioned herein?—Yes.

Name—Architect.

Address......

59. If not architect, who is to superintend the erection of the building described herein? Name.......Address.......

Owner................Address................

Architect................Address................

Mason................ Address................

Carpenter................ Address................

If a wall, or part of a wall already built is to be used, fill up the following:

THE CITY OF NEW YORK.

Borough of Manhattan, May 11th, 1913.

The undersigned gives notice that he intends to use the North and part of the West wall of building Nos. 26-28 West 39th St., as party wall in the erection of the building hereinbefore described, and respectfully requests that the same be examined and a permit granted therefor. The foundation walls are built of brick 20 in. thick, 10 feet below curb; the upper walls are built of brick 16 in. thick, 90 and 50 feet deep, 55 feet in height.

(Sign here) .... Architect.

District Inspector's Report Upon Application.

The Bureau of Buildings for the Borough of Manhattan.
The City of New York.

Borough of Manhattan .... 1913.

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

I respectfully report that I have thoroughly examined and measured the walls, named in the foregoing application, and found the foundation wall of brick to be built 20 inches thick, 10 feet below curb, the upper wall of brick built 16 inches thick, 80 and 40 feet deep, 50 feet in height, and that the mortar in said wall is cement, hard and good. The North and West walls are built as party walls, and are in a good and safe condition to be used as proposed.

What is the nature of the ground?—Rock.

What kind of sand was used in the mortar?......

(The inspector must here state what defects, if any, are in the walls).

(The inspector must state the thickness of walls in each and every story).

(Sign here) Inspector.

Final approval.

THE CITY OF NEW YORK.

Borough of Manhattan.

5/26/1913.

This is to certify that the within detailed statement of specifications, and a copy of the plans relating thereto, have been submitted to the Superintendent of Buildings for the Borough of Manhattan, and are hereby as amended approved.

(Signature)
Superintendent of Buildings.

CHAPTER XVII.

Extract From the Building Code of the City of New York.

The following articles from the Building Code are of special interest for Iron Contractors. Much trouble, defective work and expense may be saved by a careful and intelligent reading of these extracts. It is the author's candid opinion that nearly one third of the violations filed against iron work, are due to complete ignorance of even long time, experienced contractors, of the essential requirements of the code.

To illustrate this consider i. e. Sec. 117, relating to separators in double beams or beams used in pairs. Nothing can be plainer than a statement like this: "When rolled steel or wrought iron beams are used in pairs to form a girder, they shall be connected together by bolts and iron separators at intervals of not more than five feet."

It is a simple matter to punch the webs of such beams in the shop for separator bolts, not further than five feet on centers. Instead of doing this, many iron workers in ignorance of the above section of the law, will punch separator holes over five feet on centres and then erect their beams without thinking of violating the code. When a violation notice is served, they have to drill additional holes in the field, on scaffolds and under time-wasting conditions.

There is no better investment of spare time for builders, architects and mechanics, than to carefully read and understand the building code, especially the parts relating to the work going on under their supervision.

At the end of this chapter there is a quick reference table, which will be useful to the readers in locating the sections relating to various parts of their work. The numbers of all sections here given are the same as in the official code.

EXTRACTS FROM THE BUILDING CODE.

Short Title of This Ordinance. A Remedial Ordinance.

THIS ORDINANCE TO BE KNOWN AND CITED AS THE BUILDING CODE, AND PRESUMPTIVELY CONTAINS THE BUILDING LAW, EXCEPT SO FAR AS SUCH PROVISIONS ARE CONTAINED IN THE CHARTER.

Section 1. The following provisions shall constitute and be known as The Building Code and may be cited as such, and presumptively provides for all matters concerning, affecting or relating to the construction, alteration or removal of buildings or structures erected or to be erected in the City of New York, as constituted by the "Greater New York Charter," except so far as such provisions are contained in said charter.

Building Code to Be Construed Liberally.

Sec. 2. This ordinance is hereby declared to be remedial, and is to be construed liberally, to secure the beneficial interests and purposes thereof.

Filing Plans and Statements.

Sec. 4. Before the erection, construction or alteration of any building or part of any building, structure, or part of any structure, or wall, or any platform, staging or flooring to be used for standing or seating purposes, and before the construction or alteration of the plumbing or drainage of any building, structure or premises is commenced, the owner or lessee, or agent of either, or the architect or builder, employed by such owner or lessee in connection with the proposed erection or altration, shall submit to the Commissioner of Buildings for the borough in which the premises are situated a detailed statement in triplicate of the specifications, on appropriate blanks to be furnished to applicants by the Department of Buildings, and a full and complete copy of the plans of such proposed work as the Commissioner of Buildings having jurisdiction may require, all of which shall be accompanied with a statement in writing, sworn to before a notary public or commissioner of deeds, giving the full name and residence, street and number, of the owner, or of each of the owners of said building, or proposed building, structure or proposed structure, premises, wall, platform, staging or flooring. Said sworn statement, and detailed statement of specifications, and copy of the plans shall be kept on file in the office of the Commissioner of Buildings for the borough where the premises to which they relate are situated, and the erection, construction, or alteration of said building, structure, wall, platform, staging or flooring, or any part thereof, and the construction or alteration of the said plumbing or drainage, shall not be commenced or proceeded with, until said statements and plans shall have been so filed, and approved by the said Commissioner of Buildings, and the erection, construction or alteration of such building, structure, platform, staging or flooring, and the construction or alteration of such plumbing or drainage when proceeded with shall

be constructed in accordance with such approved detailed statement of specifications and copy of plans. Any approval which may be issued by a Commissioner of Buildings pursuant to the provisions of this section, but under which no work is commenced within one year from the time of issuance, shall expire by limitation. Ordinary repairs of buildings or structures, or of the plumbinb or drainage thereof, may be made without notice to the Department of Buildings, but such repairs shall not be construed to include the cutting away of any stone or brick wall, or any portion thereof, the removal or cutting of any beams or supports, or the removal, change or closing of any staircase, or the alteration of any house sewer or private sewer or drainage system, or the construction of any soil or waste pipe.

The foregoing provisions and all the provisions of this Code shall apply with equal force to buildings, both municipal and private.

Tests of New Materials.

Sec. 20. New structural material or whatever nature shall be subjected to such tests to determine its character and quality as the Commissioner of Buildings for the borough in which the material is to be used shall direct; the tests shall be made under the supervision of said Commissioner, or he may direct the architect or owner to file with him a certified copy of the results of tests, such as he may direct shall be made.

Structural Materials.

Sec. 21. **Wrought Iron.** All wrought iron shall be uniform in character, fibrous, tough and ductile. It shall have an ultimate tensile resistance of not less than 48,000 pounds per square inch, an elastic limit of not less than 24,000 pounds per square inch, and an elongation of 20 per cent. in eight inches, when tested in small specimens.

Steel. All structural steel shall have an ultimate tensile strength of from 54,000 pounds to 64,000 pounds per square inch. Its elastic limit shall be not less than 32,000 pounds per square inch and a minimum elongation of not less than 20 per cent. in eight inches. Rivet-steel shall have an ultimate strength of from 50,000 to 58,000 pounds per square inch.

Cast Steel shall be made of open hearth steel, containing one-quarter to one-half per cent. of carbon, not over eight one-hundredths of one per cent. of phosphorus, and shall be practically free from blow-holes.

Cast Iron shall be of good foundry mixture, producing a clean, tough, gray iron. Sample bars, five feet long, one inch square, cast in sand moulds, placed on supports four feet six inches apart, shall bear a central load of 450 pounds before breaking. Castings shall be free of serious blow-holes, cinder spots and cold shuts. Ultimate tensile strength shall be not less than 16,000 pounds per square inch when tested in small specimens.

Foundations.

Sec. 25. Where metal is incorporated in or forms part of a foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings. When footings of iron or steel for columns are placed below the water level, they shall be similarly coated, or enclosed in concrete, for preservation against rust.

Foundation Walls.

Sec. 26. Foundation walls shall be construed to include all walls and piers built below the curb level, or nearest tier of beams to the curb, to serve as supports for walls, piers, columns, girders, posts or beams.

The footing or base course shall be of stone or concrete, or both, or of concrete and stepped-up brickwork, of sufficient thickness and area to safely bear the weight to be imposed thereon. If the footing or base course be of concrete, the concrete shall not be less than twelve inches thick. If of stone, the stones shall not be less than two by three feet, and at least eight inches in thickness for walls; and not less than ten inches in thickness if under piers, columns or posts; the footing or base course, whether formed of concrete or stone, shall be at least twelve inches wider than the bottom width of walls, and at least twelve inches wider on all sides than the bottom width of said piers, columns or posts.

If the superimposed load is such as to cause undue transverse strain on a footing projecting twelve inches, the thickness of such footing is to be increased so as to carry the load with safety. For small structures and for small piers sustaining light loads, the Commissioner of Buildings having jurisdiction may, in his discretion, allow a reduction in the thickness and projection for footing or base courses herein specified.

If, in place of a continuous foundation wall, isolated piers are to be built to support the superstructure, grillage

beams of wrought iron or steel resting on a proper concrete bed may be used. Such beams must be provided with separators and bolts inclosed and filled solid between with concrete, and of such sizes and so arranged as to transmit with safety the superimposed loads.

Walls and Piers.

Sec. 28. Bearing walls shall be taken to mean those walls on which the beams, girders or trusses rest.

The walls and piers of all buildings shall be properly and solidly bonded together with close joints filled with mortar.

All piers shall be built of stone or good, hard, well burnt brick laid in cement mortar. Every pier built of brick, containing less than nine superficial feet at the base, supporting any beam, girder, arch or column on which a wall rests, or lintel spanning an opening over ten feet and supporting a wall, shall at intervals of not over thirty inches apart in height have built into it a bond stone not less than four inches thick, or a cast iron plate of sufficient strength and the full size of the piers. For piers fronting on a street the bond stones may conform with the kind of stone used for the trimmings of the front. Cap stones of cut granite or bluestone, proportioned to the weight to be carried, but not less than five inches in thickness, by the full size of the pier, or cast-iron plates of equal strength by the full size of the pier, shall be set under all columns or girders, except where a four-inch bond stone is placed immediately below said cap stone, in which case the cap stone may be reduced in horizontal dimensions at the discretion of the Commissioner of Buildings having jurisdiction.

Walls Tied, Anchored and Braced.

Sec. 41. All exterior piers shall be anchored to the beams or girders on the level of each tier.

Arches and Lintels.

Sec. 42. Openings for doors and windows in all buildings shall have good and sufficient arches of stone, brick or terra cotta, well built and keyed with good and sufficient abutments, or lintels of stone, iron or steel of sufficient strength, which shall have a bearing at each end of not less than five inches on the wall. On the inside of all openings in which lintels shall be less than the thickness of the wall to be supported there shall be timber lintels, which shall rest at each end not more than three inches

on any wall, which shall be chamfered at each end, and shall have a suitable arch turned over the timber lintel. Or the inside lintel may be of cast iron, or wrought iron or steel, and in such case stone blocks or cast iron plates shall not be required at the ends where the lintel rests on the walls, provided the opening is not more than six feet in width.

Brick and Hollow Tile Partitions.

Sec. 49. Eight-inch brick and six-inch and four-inch hollow tile partitions, of hard-burnt clay or porous terra-cotta, may be built, not exceeding in their vertical portions a measurement of fifty, thirty-six and twenty-four feet respectively, and in their horizontal measurement a length not exceeding seventy-five feet, unless strengthened by proper cross-walls, piers or buttresses, or built in iron or steel framework. All such partitions shall be carried on proper foundations, or on iron or steel girders, or on iron or steel girders and columns or piers of masonry.

Anchors and Straps for Wood Beams and Girders.

Sec. 60. Each tier of beams shall be anchored to the side, front, rear or party walls at intervals of not more than six feet apart, with good, strong wrought iron anchors of not less than one and a half inches by three-eighths of an inch in size, well fastened to the side of the beams by two or more nails made of wrought iron at least one-fourth of an inch in diameter. Where the beams are supported by girders, the girders shall be anchored to the walls and fastened to each other by suitable iron straps. The ends of wood beams resting upon girders shall be butted together end to end and strapped by wrought iron straps of the same size and distance apart and in the same beam as the wall anchors, and shall be fastened in the same manner as said wall anchors. Or they may lap each other at least twelve inches, and be well spiked or bolted together where lapped.

Each tier of beams front and rear, opposite each pier, shall have hard wood anchor strips dovetailed into the beams diagonally, which strips shall cover at least four beams and be one inch thick and four inches wide, but no such anchor strips shall be let in within four feet of the centre line of the beams; or wood strips may be nailed on the top of the beams and kept in place until the floors are being laid. Every pier and wall, front or rear, shall be well anchored to the beams of each story, with the same size anchors as are required for side walls, which anchors shall hook over the fourth beam.

Wood Columns and Plates.

Sec. 61. All timber columns shall be squared at the ends perpendicular to their axes. To prevent the unit stresses from exceeding those fixed in this Code, timber or iron cap and base plates shall be provided. Additional iron cheek plates shall be placed between the cap and the base plates and bolted to the girders when required to transmit the loads with safety.

Engineers' Stationary Ladders.

Sec. 76. Every building in which boilers or machinery are placed in the cellar or lowest story shall have stationary iron ladders or stairs from such story leading direct to a manhole above, on the sidewalk or other outside exit.

Metal Skylights.

Sec. 78. All skylights having a superficial area of more than nine square feet, placed in any building, shall have the sashes and frames thereof constructed of iron and glass.

Tanks.

Sec. 93. Tanks containing more than five hundred gallons of water or other fluid hereafter placed in any story, or on the roof or above the roof of any building now or hereafter erected, shall be supported on iron or steel beams of sufficient strength to safely carry the same; and the beams shall rest at both their ends on brick walls or on iron or steel girders or iron or steel columns or piers of masonry.

Covers on top of water tanks placed on roof, if of wood shall be covered with tin.

Fire Escapes.

Sec. 103. Every dwelling-house occupied by or built to be occupied by three or more families, and every building already erected, or that may hereafter be erected, more than three stories in height, occupied and used as a hotel or lodging-house, and every boarding-house, having more than fifteen sleeping rooms above the basement story, and every factory, mill, manufactory or workshop, hospital, asylum or institution for the care or treatment of individuals, and every building three stories and over in height used or occupied as a store or workroom, and every building in whole or in part occupied or used as a school or place of

instruction or assembly, and every office building five stories or more in height, shall be provided with such good and sufficient fire-escapes, stairways, or other means of egress in case of fire as shall be directed by the Department of Buildings.

Fireproof Buildings.

Sec. 105. Every building hereafter erected or altered, to be used as a hotel, lodging house, school, theatre, jail, police station, hospital, asylum, institution for the care or treatment of persons, the height of which exceeds thirty-five feet, excepting all buildings for which specifications and plans have been hertofore submitted to and approved by the Department of Buildings, and every other building the height of which exceeds seventy-five feet, except as herein otherwise provided, shall be built fireproof, that is to say:

They shall be constructed with walls of brick, stone, Portland cement concrete, iron or steel, in which wood beams or lintels shall not be placed, and in which the floors and roofs shall be of materials provided for in Section 106 of this Code.

The stairs and staircase landings shall be built entirely of brick, stone, Portland cement concrete, iron or steel.

No woodwork or other inflammable material shall be used in any of the partitions, furrings or ceilings in any such fireproof buildings, excepting, however, that when the height of the building does not exceed twelve stories nor more than one hundred and fifty feet, the doors and windows and their frames, the trims, the casings, the interior finish when filled solid at the back with fireproof material, and the floor boards and sleepers directly thereunder, may be of wood, but the space between the sleepers shall be solidly filled with fireproof materials and extend up to the under side of the floor boards. When the height of a fireproof building exceeds twelve stories, or more than 150 feet, the floor surfaces shall be of stone, cement, rock, asphalt, tiling or similar incombustible material, or the sleepers and floors may be of wood treated by some process, approved by the Board of Buildings, to render the same fireproof. All outside window frames and sash shall be of metal, or of wood covered with metal. The inside window frames and sash, doors, trim, and other interior finish may be of wood covered with metal, or of wood treated by some process approved by the Board of Buildings to render the same fireproof.

All hall partitions or permanent partitions between rooms in fireproof buildings shall be built of fireproof material and

shall not be started on wood sills, nor on wood floor boards, but be built upon the fireproof construction of the floor and extend to the fireproof beam filling above.

Fireproof Floors.

Sec. 106. Fireproof floors shall be constructed with wrought iron or steel floor beams so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an inch per foot of span under the total load; and they shall be tied together at intervals of not more than eight times the depth of the beam. Between the wrought iron or steel floor beams shall be placed brick arches springing from the lower flange of the steel beams.

Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for spans over five feet, or such thickness as may be required by the Board of Buildings. * * * Or the space between the beams may be filled in with hollow tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn. * * * The said arches shall be of a depth and sectional area to carry the load to be imposed thereon, without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarter inches for each foot of span. * * *

Or the space between the beams may be filled with arches of Portland cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams. The concrete shall be not less than four inches in thickness at the crown of the arch. * * * These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square. Or between the said beams may be placed solid or hollow burnt-clay, stone, brick or concrete slabs in flat or curved shapes, concrete or other fireproof composition, and any of said materials may be used in combination with wire cloth, expanded metal, wire strands, or wrought iron or steel bars; but in any such construction and as a precedent condition to the same

being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Board of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test. * * *

No filling of any kind which may be injured by frost shall be placed between said floor beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen. * * * Temporary centering when used in placing fireproof systems between floor beams, shall not be removed within twenty-four hours or until such time as the mortar or material has set. All fireproof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load.

The bottom flanges of all wrought iron or rolled steel floor and flat roof beams, and all exposed portions of such beams below the abutments of the floor arches, shall be entirely encased with hard-burnt clay, porous terra-cotta or other fireproof material allowed to be used for the filling between the beams under the provisions of this section, such encasing material to be properly secured to the beams.

The exposed sides and bottom plates or flanges of wrought iron or rolled steel girders supporting iron or steel floor beams, or supporting floor arches or floors, shall be entirely encased in the same manner. Openings through fireproof floors for pipes, conduits and similar purposes shall be shown on the plans. After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron, and such openings shall be filled in with fireproof material after the pipes or conduits are in place.

Encasing Interior Columns.

Sec. 107. All cast iron, wrought iron or rolled columns, including the lugs and brackets on same, used in the interior of any fireproof building, or used to support any fireproof floor, shall be protected with not less than two inches of fireproof material securely applied. The extreme outer edge of lugs, brackets and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

IRON AND STEEL CONSTRUCTION.

Skeleton Construction.

Sec. 110. Where columns are used to support iron or steel girders carrying enclosure walls, the said columns shall be of cast iron, wrought iron, or rolled steel, and on their exposed outer and inner surfaces shall be constructed to resist fire by having a casing of brickwork not less than eight inches in thickness on the outer surfaces, nor less than four inches in thickness on the inner surfaces, and all bonded into the brickwork of the enclosure walls. The exposed sides of the iron or steel girders shall be similarly covered in with brickwork not less than four inches in thickness on the outer surfaces and tied and bonded, but the extreme outer edge of the flanges of beams, or plates or angles connected to the beams, may project to within two inches of the outside surface of the brick casing. The inside surfaces of girders may be similarly covered with brickwork, or if projecting inside of the wall, they shall be protected by terra-cotta, concrete or other fireproof material. Girders for the support of the enclosure walls shall be placed at the floor line of each story.

Steel and Wrought Iron Columns.

Sec. 111. No part of a steel or wrought iron column shall be less than one-quarter of an inch thick. No wrought iron or rolled steel column shall have an unsupported length of more than forty times its least lateral dimension or diameter, except as modified by section 138 of this Code, and also except in such cases as the Commissioner of Buildings may specially allow a greater unsupported length. The ends of all columns shall be faced to a plane surface at right angles to the axis of the columns, and the connection between them shall be made with splice plates. The joint may be effected by rivets of sufficient size and number to transmit the entire stress, and then the splice plates shall be equal in sectional area to the area of column spliced. When the section of the columns to be spliced is such that spliced plates cannot be used, a connection formed of plates and angles may be used, designed to properly distribute the stress. No material, whether in the body of the column or used as lattice-bar or stay-plate, shall be used in any wrought iron or steel column of less thickness than one-thirty-second of its unsupported width measured between centers of rivets transversely, or one-sixteenth the distance between centers of rivets in the direction of the stress.

Stay-plates are to have not less than four rivets, and are to be spaced so that the ratio of length by the least radius of gyration of the parts connected does not exceed forty; the distance between nearest rivets of two stay-plates shall in this case be considered as length. Steel and wrought iron columns shall be made in one, two or three-story lengths, and the materials shall be rolled in one length wherever practicable to avoid intermediate splices. Where any part of the section of a column projects beyond that of the column below, the difference shall be made up by filling plates secured to column by the proper number of rivets. Shoes of iron or steel, as described for cast iron columns, or built shoes of plates and shapes, may be used complying with same requirements.

Cast Iron Columns.

Sec. 112. Cast iron columns shall not have less diameter than five inches or less thickness than three-quarters of an inch. Nor shall they have an unsupported length of more than twenty times their least lateral dimensions or diameter, except as modified by section 138 of this Code, and except the same may form part of an elevator enclosure or staircase, and also except in such cases as the Commissioner of Buildings having jurisdiction may specially allow a greater unsupported length. All cast iron columns shall be of good workmanship and material. The top and bottom flanges, seats and lugs shall be of ample strength, reinforced by fillets and brackets; they shall not be less than one inch in thickness when finished. All columns must be faced at the ends to a true surface perpendicular to the axis of the column. Column joints shall be secured by not less than four bolts each, not less than three-quarters of an inch in diameter. The holes for these bolts shall be drilled to a template. The core of a column below a joint shall be not larger than the core of the column above and the metal shall be tapered down for a distance of not less than six inches, or a joint plate may be inserted of sufficient strength to distribute the load. The thickness of metal shall be not less than one-twelfth the diameter or the greatest lateral dimension of cross-section, but never less than three-quarters of an inch. Wherever the core of a cast iron column has shifted more than one-fourth the thickness of the shell, the strength shall be computed assuming the thickness of metal all around equal to the thinnest part, and the column shall be condemned if this computation shows the strength to be less than required by this Code. Wherever blowholes

or imperfections are found in a cast iron column which reduces the area of the cross-section at that point more than ten per cent., such column shall be condemned. Cast iron posts or columns not cast with one open side or back, before being set up in place, shall have a three-eighths of an inch hole drilled in the shaft of each post or column by the manufacturer or contractor furnishing the same, to exhibit the thickness of the castings; and any other similar sized hole or holes which the Commissioner of Buildings may require, shall be drilled in the said posts or columns by the said manufacturer or contractor at his own expense.

Double Columns.

Sec. 113. In all buildings hereafter erected or altered, where any iron or steel column or columns are used to support a wall or part thereof, whether the same be an exterior or an interior wall, and columns located below the level of the sidewalk, which are used to support exterior walls or arches over vaults, the said column or columns shall be either constructed double, that is, an outer and an inner column, the inner column alone to be of sufficient strength to sustain safely the weight to be imposed thereon, and the outer columns shall be one inch shorter than the inner columns, or such other or steel column of sufficient strength and protected with not less than two inches of fireproof material securely applied, except that double or protected columns shall not be required for walls fronting on streets or courts.

Party Wall Posts.

Sec. 114. If iron or steel posts are to be used as party posts in front of a party wall, and intended for two buildings, then the said posts shall be not less in width than the thickness of the party wall, nor less in depth than the thickness of the wall to be supported above. Iron or steel posts in front of side, division or party walls, shall be filled up solid with masonry and made perfectly tight between the posts and walls. Intermediate posts may be used, which shall be sufficiently strong, and the lintels thereon shall have sufficient bearings to carry the weight above with safety.

Plates Between Joints of Open Back Columns.

Sec. 115. Iron or steel posts or columns with one or more open sides and backs shall have solid iron plates on top of each, excepting where pierced for the passage of pipes.

Steel and Iron Girders.

Sec. 116. Rivets in flanges shall be spaced so that the least value of a rivet for either shear or bearing is equal or greater than the increment of strain due to the distance between adjoining rivets. All other rules given under riveting shall be followed. The length of rivets between heads shall be limited to four times the diameter. The compression flange of plate girders shall be secured against buckling if its length exceeds thirty times its width. If splices are used they shall fully make good the members spliced in either tension or compression. Stiffeners shall be provided over supports and under concentrated loads; they shall be of sufficient strength, as a column, to carry the loads, and shall be connected with a sufficient number of rivets to transmit the stresses into the web plate. Stiffeners shall fit so as to support the flanges of the girders. If the unsupported depth of the web plate exceeds sixty times its thickness, stiffeners shall be used at intervals not exceeding 120 times the thickness of the web.

Rolled Steel and Wrought Iron Beams Used as Girders.

Sec. 117. When rolled steel or wrought iron beams are used in pairs to form a girder, they shall be connected together by bolts and iron separators at intervals of not more than five feet. All beams twelve inches and over in depth shall have at least two bolts to each separator.

Cast Iron Lintels.

Sec. 118. Cast iron lintels shall not be used for spans exceeding sixteen feet. Cast iron lintels or beams shall be not less than three-quarters of an inch in thickness in any of their parts.

Plates Under Ends of Lintels and Girders.

Sec. 119. When the lintels or girders are supported at the ends by brick walls or piers they shall rest upon cut granite or bluestone blocks at least ten inches thick, or upon cast iron plates of equal strength by the full size of the bearings. In case the opening is less than twelve feet, the stone blocks may be five inches in thickness, or cast iron plates of equal strength by the full size of the bearings, may be used, provided that in all cases the safe loads do not exceed those fixed by section 139 of this Code.

Rolled Steel and Wrought Iron Floor and Roof Beams.

Sec. 120. All rolled steel and wrought iron floor and roof beams used in buildings shall be of full weight, straight and free from injurious defects. Holes for tie rods shall be placed as near the thrust of the arch as practicable. The distance between tie rods in floors shall not exceed eight feet, and shall not exceed eight times the depth of floor beams twelve inches and under. Channels and other shapes where used as skewbacks, shall have a sufficient resisting moment to take up the thrust of the arch. Bearing plates of stone or metal shall be used to reduce the pressure on the wall to the working stress. Beams resting on girders shall be securely riveted or bolted to the same; where joined on a girder, tie straps of one-half inch net sectional area shall be used, with rivets or bolts to correspond. Anchors shall be provided at the ends of all such beams bearing on walls.

Templates Under Ends of Steel or Iron Floor Beams.

Sec. 121. Under the ends of all iron or steel beams where they rest on the walls, a stone or cast iron template shall be built into the walls. Templates under ends of steel or iron beams shall be of such dimensions as to bring no greater pressure upon the brickwork than that allowed by section 139 of this Code. When rolled iron or steel floor beams, not exceeding six inches in depth, are placed not more than thirty inches on centers no templates shall be required.

Framing and Connecting Structural Work.

Sec. 122. All iron or steel trimmer beams, headers, and tail beams, shall be suitably framed and connected together, and the iron or steel girders, columns, beams, trusses and all other iron work of all floors and roofs shall be strapped, bolted, anchored and connected together, and to the walls.

All beams framed into and supported by other beams or girders, shall be connected thereto by angles or knees of a proper size and thickness, and have sufficient bolts or rivets in both legs of each connecting angle to transmit the entire weight or load coming on the beam to the supporting beam or girder. In no case shall the shearing value of the bolts or rivets, or the bearing value of the connection angles, provided for in section 139 of this Code, be exceeded.

Riveting of Structural Steel and Wrought Iron Work.

Sec. 123. The distance from centre of a rivet hole to the edge of the material shall be not less than:

5/8 of an inch for 1/2 inch rivets.
7/8 of an inch for 5/8 inch rivets.
1 1/8 of an inch for 3/4 inch rivets.
1 3/8 of an inch for 7/8 inch rivets.
1 1/2 of an inch for 1 inch rivets.

Wherever possible, however, the distance shall be equal to two diameters. All rivets, wherever practicable, shall be machine driven. The rivets in connections shall be proportioned and placed to suit the stresses. The pitch of rivets shall never be less than three diameters of the rivet nor more than six inches. In the direction of the stress it shall not exceed sixteen times the least thickness of the outside member. At right angles to the stress it shall not exceed thirty-two times the least thickness of the outside member. All holes shall be punched accurately, so that upon assembling a cold rivet will enter the hole without straining the material by drifting. Occasional slight errors shall be corrected by reaming. The rivets shall fill the holes completely; the heads shall be hemispherical and concentric with the axis of the rivet. Gussets shall be provided wherever required, of sufficient thickness and size to accommodate the number of rivets necessary to make a connection.

Bolting of Structural Steel and Wrought Iron Work.

Sec. 124. Where riveting is not made mandatory connections may be effected by bolts. These bolts shall be of wrought iron or mild steel, and they shall have U. S. standard threads. The threads shall be full and clean, the nut shall be truly concentric with the bolt, and the thread shall be of sufficient length to allow the nut to be screwed up tightly. When bolts go through bevel flanges, bevel washers to match shall be used, so that head and nut of bolt are parallel. When bolts are used for suspenders, the working stresses shall be reduced for wrought iron to 10,000 pounds, and for steel to 14,000 pounds per square inch of net area, and the load shall be transmittd into the head or nut by strong washers distributing the pressure evenly over the entire surface of the same. Turned bolts in reamed holes shall be deemed a substitute for field rivets.

Steel and Wrought Iron Trusses.

Sec. 125. Trusses shall be of such design that the stresses in each member can be calculated. All trusses shall be held rigidly in position by efficient systems of lateral and sway bracing, struts being spaced so that the maximum

limit of length to least radius of gyration, established in Section 111 of this Code, is not exceeded. Any member of a truss subjected to transverse stress, in addition to direct tension or compression, shall have the stresses causing such strain added to the direct stresses coming on the member, and the total stresses thus formed shall in no case exceed the working stresses stated in Section 139 of this Code.

Riveted Steel and Wrought Iron Trusses.

Sec. 126. For tension members, the actual net area only, after deducting rivet holes one-eighth inch larger than the rivets, shall be considered as resisting the stress. If tension members are made of angle irons riveted through one flange only, only that flange shall be considered in proportioning areas. Rivets to be proportioned as prescribed in Section 123 of this Code. If the axes of two adjoining web members do not intersect within the line of the chords, sufficient area shall be added to the chord to take up the bending strains. No bolts shall be used in the connections of riveted trusses, excepting when riveting is impracticable, and then the holes shall be drilled or reamed.

Steel and Iron Pin-connected Trusses.

Sec. 127. The bending stresses on pins shall be limited to 20,000 pounds for steel and 15,000 pounds for iron. All compression members in pin-connected trusses shall be proportioned, using 75 per cent. of the permissible working stress for columns. The heads of all eye-bars shall be made by upsetting or forging. No weld will be allowed in the body of the bar. Steel eye-bars shall be annealed. Bars shall be straight before boring. All pin-holes shall be bored true and at right angles to the axis of the members, and must fit the pin within one-thirty-second of an inch. The distances of pin-holes from centre to centre for corresponding members shall be alike, so that, when piled upon one another, pins will pass through both ends without forcing. Eyes and screw ends shall be so proportioned that upon test to destruction, fracture will take place in the body of the member. All pins shall be accurately turned. Pin-plates shall be provided wherever necessary to reduce the stresses on pins to the working stresses prescribed in Section 139 of this Code. These pin-plates shall be connected to the members by rivets of sufficient size and number to transmit the stresses without exceeding working stresses. All rivets in members of pin-connected trusses shall be machine driven. All rivets in pin-plates which are necessary to transmit stress

shall be also machine driven. The main connections of members shall be made by pins. Other connections may be made by bolts. If there is a combination of riveted and pin-connected members in one truss, these members shall comply with the requirements for pin-connected trusses; but the riveting shall comply with the requirements of Section 126 of this Code.

Iron and Other Metal Fronts to be Filled in.

Sec. 128. All cast iron or metal fronts shall be backed up or filled in with masonry.

Painting of Structural Metal Work.

Sec. 129. All structural metal work shall be cleaned of all scale, dirt and rust, and be thoroughly coated with one coat of paint. Cast iron columns shall not be painted until after inspection by the Department of Buildings. Where surfaces in riveted work come in contact, they shall be painted before assembling. After erection all work shall be painted at least one additional coat. All iron or steel used under water shall be enclosed with concrete.

Floor Loads.

Sec. 130. The dead loads in all buildings shall consist of the actual weight of walls, floors, roofs, partitions and all permanent construction.

The live or variable loads shall consist of all loads other than dead loads.

Every floor shall be of sufficient strength to bear safely the weight to be imposed thereon in addition to the weight of the materials of which the floor is composed; if to be used as a dwelling house, apartment house, tenement house, hotel or lodging house, each floor shall be of sufficient strength in all its parts to bear safely upon every superficial foot of its surface not less than sixty pounds; if to be used for office purposes, not less than seventy-five pounds upon every superficial foot above the first floor, and for the latter floor 150 pounds; if to be used as a school or place of instruction, not less than seventy-five pounds upon every superficial foot; if to be used for stable and carriage house purposes, not less than seventy-five pounds upon every superficial foot; if to be used as a place of public assembly, not less than ninety pounds upon every superficial foot; if to be used for ordinary stores, light manufacturing and light storage, not less than 120 pounds upon every superficial foot; if to be

used as a store where heavy materials are kept or stored, warehouse, factory, or for any other manufacturing or commercial purpose, not less than 150 pounds upon every superficial foot.

The strength of factory floors intended to carry running machinery shall be increased above the minimum given in this section in proportion to the degree of vibratory impulse liable to be transmitted to the floor, as may be required by the Commissioner of Buildings having jurisdiction. The roofs of all buildings having a pitch of less than twenty degrees shall be proportioned to bear safely fifty pounds upon every superficial foot of their surface, in addition to the weight of materials composing the same. If the pitch be more than twenty degrees the live load shall be assumed at thirty pounds upon every superficial foot, measured on a horizontal plane. For sidewalks between the curb and area lines the live load shall be taken at 300 pounds upon every superficial foot.

Load on Floors to be Distributed.

Sec. 131. The weight placed on any of the floors of any building shall be safely distributed thereon. The Commissioner of Buildings having jurisdiction may require the owner or occupant of any building, or of any portion thereof, to redistribute the load on any floor, or to lighten such load, where he deems it to be necessary.

Strength of Temporary Supports.

Sec. 133. Every temporary support placed under any structure, wall, girder or beam, during the erection, finishing, alteration, or repairing of any building or structure or any part thereof, shall be of sufficient strength to safely carry the load to be placed thereon.

Safe Load for Masonry Work.

Sec. 134. The safe-bearing load to apply to brickwork shall be taken at eight tons per superficial foot, when lime mortar is used; eleven and one-half tons per superficial foot when lime and cement mortar mixed is used; fifteen tons per superficial foot when cement mortar is used. The safe-bearing load to apply to rubble-stone work shall be taken at ten tons per superficial foot when Portland cement is used; when cement other than Portland is used, eight tons per superficial foot; when lime and cement mortar mixed is used, seven tons per superficial foot, and when lime mortar

is used, five tons per superficial foot. The safe-bearing load to apply to concrete when Portland cement is used shall be taken at fifteen tons per superficial foot, and when cement other than Portland is used, eight tons per superficial foot.

Weights of Certain Materials.

Sec. 135. In computing the weight of walls, a cubic foot of brickwork shall be deemed to weigh 115 pounds. Sandstone, white marble, granite and other kinds of building stone shall be deemed to weigh 170 pounds per cubic foot.

Computations for Strength of Materials.

Sec. 136. The dimensions of each piece or combination of materials required shall be ascertained by computation, according to the rules prescribed by this Code.

Factors of Safety.

Sec. 137. Where the unit stress for any material is not prescribed in this Code the relation of allowable unit stress to ultimate strength shall be as one to four for metals, subjected to tension or transverse stress; as one to six for timber, and as one to ten for natural or artificial stones and brick or stone masonry. But wherever working stresses are prescribed in this Code, varying the factors of safety hereinabove given, the said working stresses shall be used.

Strength of Columns.

Sec. 138. In columns or compression members with flat ends of cast iron, steel, wrought iron or wood, the stress per square inch shall not exceed that given in the following tables:

When the length divided by least radius of gyration equals	Working Stresses Per Square Inch of Section. Cast Iron.	Steel.	Wrought Iron.
120	......	8,240	4,400
110	......	8,820	5,200
100	......	9,400	6,000
90	......	9,980	6,800
80	......	10,560	7,600
70	9,200	11,140	8,400
60	9,500	11,720	9,200
50	9,800	12,300	10,000
40	10,100	12,880	10,800
30	10,400	13,460	11,600
20	10,800	14,040	12,400
10	11,000	14,620	13,200

And in like proportion for intermediate ratios.

When the Length Divided by the Least Diameter Equals	Working Stresses Per Square Inch of Section. Long Leaf Yellow Pine.	White Pine Norway Pine Spruce.	Oak.
30	460	350	390
25	550	425	475
20	640	500	560
15	730	575	645
12	784	620	696
10	820	650	730

And in like proportion for intermediate ratios. Five-eighths the values given for white pine shall also apply to chestnut and hemlock posts. For locust posts use one and one-half the value given for white pine. Columns and compression members shall not be used having an unsupported length of greater ratios than given in the tables.

Any column eccentrically loaded shall have the stresses caused by such eccentricity computed, and the combined stresses resulting from such eccentrity at any part of the column, added to all other stresses at that part, shall in no case exceed the working stresses stated in this Code.

The eccentric load of a column shall be considered to be distributed equally over the entire area of that column at the next point below at which the column is securely braced laterally in the direction of the eccentricity.

Working Stresses.

Sec. 139. The safe carrying capacity of the various materials of construction (except in the case of columns) shall be determined by the following working stresses in pounds per square inch of sectional area:

Compression (Direct).

Rolled steel	16,000
Cast steel	16,000
Wrought iron	12,000
Cast iron (in short blocks)	16,000
Steel pins and rivets (bearing)	20,000
Wrought iron pins and rivets (bearing)	15,000

	With Grain.	Across Grain.
Oak	900	800
Yellow pine	1,000	600
White pine	800	400

	With Grain.	Across Grain.
Spruce	800	400
Locust	1,200	1,000
Hemlock	500	500
Chestnut	500	1,000
Concrete (Portland) cement, 1; sand, 2; stone, 4		230
Concrete (Portland) cement, 1; sand, 2; stone, 5		208
Concrete, Rosendale, or equal, cement, 1; sand, 2; stone, 4		125
Concrete, Rosendale, or equal, cement, 1; sand, 2; stone 5		111
Rubble stonework in Portland cement mortar		140
Rubble stonework in Rosendale cement mortar		111
Rubble stonework in lime and cement mortar		97
Rubble stonework in lime mortar		70
Brickwork in Portland cement mortar; cement, 1; sand, 3		250
Brickwork in Rosendale, or equal cement mortar; cement, 1; sand, 3		208
Brickwork in lime and cement mortar; cement, 1; lime, 1; sand, 6		160
Brickwork in lime mortar; lime, 1; sand, 4		111
Granite (according to test)	1,000 to	2,400
Greenwich stone		1,200
Gneiss (New York City)		1,300
Limestones (according to test)	700 to	2,300
Marbles (according to test)	600 to	1,200
Sandstones (according to test)	400 to	1,600
Bluestone, North River		2,000
Brick (Haverstraw, flatwise)		300
Slate		1,000

Tension (Direct).

Rolled steel	16,000
Cast steel	16,000
Wrought iron	12,000
Cast iron	3,000
Yellow pine	1,200
White pine	800
Spruce	800
Oak	1,000
Hemlock	600

Shear.

Steel web plates	9,000
Steel shop rivets and pins	10,000
Steel field rivets	8,000
Steel field bolts	7,000
Wrought iron web plates	6,000
Wrought iron shop rivets and pins	7,500
Wrought iron field rivets	6,000
Wrought iron field bolts	5,500
Cast iron	3,000

	With Fibre.	Across Fibre.
Yellow pine	70	500
White pine	40	250
Spruce	50	320
Oak	100	600
Locust	100	720
Hemlock	40	275
Chestnut		150

Safe Extreme Fibre Stresses (Bending).

Rolled steel beams	16,000
Rolled steel pins, rivets and bolts	20,000
Riveted steel beams (net flange section)	14,000
Rolled wrought iron beams	12,000
Rolled wrought iron pins, rivets and bolts	15,000
Riveted wrought iron beams (net flange section)	12,000
Cast iron, compression side	16,000
Cast iron, tension side	3,000
Yellow pine	1,200
White pine	800
Spruce	800
Oak	1,000
Locust	1,200
Hemlock	600
Chestnut	800
Granite	180
Greenwich stone	150
Gneiss (New York City)	150
Limestone	150
Slate	400
Marble	120
Sandstone	100
Bluestone (North River)	300

Concrete (Portland) cement, 1; sand, 2; stone, 4	30
Concrete (Portland) cement, 1; sand, 2; stone, 5	20
Concrete (Rosendale, or equal) cement, 1; sand, 2; stone, 4	16
Concrete (Rosendale, or equal) cement, 1; sand, 2; stone, 5	10
Brick (common)	50
Brickwork (in cement)	30

Wind Pressure.

Sec. 140. All structures exposed to wind shall be designed to resist a horizontal wind pressure of thirty pounds for every square foot of surface thus exposed, from the ground to the top of same, including roof, in any direction. In no case shall the overturning moment due to wind pressure exceed seventy-five per centum of the moment of stability of the structure. In all structures exposed to wind, if the resisting moments of the ordinary materials of construction, such as masonry, partitions, floors and connections are not sufficient to resist the moment of distortion due to wind pressure, taken in any direction on any part of the structure, additional bracing shall be introduced sufficient to make up the difference in the moments. In calculations for wind bracing, the working stresses set forth in this Code may be increased by fifty per centum. In buildings under 100 feet in height, provided the height does not exceed four times the average width of the base, the wind pressure may be disregarded.

Appeals and Modifications of Law—The Board of Buildings.

Sec. 148. Each Commissioner of Buildings shall have power, with the approval of the Board, to vary or modify any rule or regulation of the Board, or the provisions of Chapter 12 of the Greater New York Charter, or of any existing law or ordinance relating to the construction, alteration or removal of any building or structure erected or to be erected within his jurisdiction, pursuant to the provisions of Section 650 of the Greater New York Charter.

Board of Examiners.

Sec. 149. The Board of Examiners for the Boroughs of Manhattan and The Bronx shall be constituted as prescribed

by Section 649 of the Greater New York Charter. Each of said examiners shall take the usual oath of office before entering upon his duties. No member of said Board shall pass upon any question in which he is pecuniarily interested. The said Board shall meet as often as once in each week, upon notice from the Commissioner of Buildings.

The members of said Board of Examiners, and the Clerk of said Board, shall each be entitled to and shall receive ten dollars for each attendance at a meeting of said Board, to be paid by the Comptroller from the annual appropriation to be made therefor upon the voucher of the Commissioner of Buildings for the Boroughs of Manhattan and The Bronx.

Violations and Penalties—Courts Having Jurisdiction.

Sec. 150. The owner or owners of any building, structure or part thereof, or wall, or any platform, staging or flooring to be used for standing or seating purposes where any violation of this Code shall be placed, or shall exist, and any architect, builder, plumber, carpenter or mason who may be employed or assist in the commission of any such violation, and any and all persons who shall violate any of the provisions of this Code, or fail to comply therewith, or any requirement thereof, or who shall violate or fail to comply with any order or regulation made thereunder, or who shall build in violation of any detailed statement of specifications or plans, submitted and approved thereunder, or of any certificate or permit issued thereunder, shall severally, for each and every such violation and non-compliance, respectively, forfeit and pay a penalty in the sum of fifty dollars. Except that any such person who shall violate any of the provisions of this Code as to the construction of chimneys, fire-places, flues, hot-air pipes and furnaces, or who shall violate any of the provisions of this Code, with reference to the framing or trimming of timbers, girders, beams, or other woodwork in proximity to chimney flues or fire-places, shall forfeit and pay a penalty in the sum of one hundred dollars. But if any said violation shall be removed or be in process of removal within ten days after the service of a notice as hereinafter prescribed, the liability of such a penalty shall cease, and the Corporation Counsel, on request of the Commissioner of Buildings having jurisdiction, shall discontinue any action pending to recover the same, upon such removal or the completion thereof within a reasonable time. Any and all of the afore-mentioned persons who having been served with a notice as hereinafter prescribed, to remove any violation, or comply with any requirement of

this Code, or with any order or regulation made thereunder, shall fail to comply with said notice within ten days after such service or shall continue to violate any requirement of this Code in the respect named in said notice shall pay a penalty of two hundred and fifty dollars. For the recovery of any said penalty or penalties an action may be brought in any municipal court, or court of record, in said city in the name of the City of New York. * * *

Officers of Department May Enter Buildings.

Sec. 160. All the officials of the Department of Buildings, so far as it may be necessary for the performance of their respective duties, have the right to enter any building or premises in said city upon showing their badge of office.

CHAPTER XVIII.

Building Code Memo for Reference to Important Points.

General.

Sec. 4. Work contrary to approved plans; working without a permit.

Fireproofing.

Sec. 105. Public buildings and all buildings over 75 ft. to be fireproof. Fireproof buildings defined.

Sec. 106. Testing floor arches; fireproofing beams.

Section 107. All interior iron columns to have not less than 2″ of fireproofing and all lugs and brackets not less than ⅞″ of fireproofing.

Sec. 110. Where walls are carried on steel, all columns to have not less than 8 in. of fireproofing on the outside face and not less than 4 in. on the inside faces.

All girders carrying brick walls to have not less than 4 in. of fireproofing, except flange edges and projections, which must have not less than 2 in.

Grillage.

Sec. 25. Grillage; all metal in foundations and all metal below water level to be protected from rust by concrete, paint, asphaltum or in other approved manner.

Sec. 26. Grillage beams to be provided with bolts and separators and to be filled solid in between with concrete.

Sec. 129. Iron or steel under water to be enclosed in concrete.

Cast Iron.

Sec. 21. Cast iron shall be good foundry mixture.

Sec. 112. Cast iron columns, minimum 5x¾ inches thick. Column joints to have not less than 4 bolt holes. Flanges and brackets not less than 1 inch thick. Shell thickness not less than 1/12 diameter or greatest lateral dimension of cross-section. Imperfections not to reduce sectional area by more than 10 per cent. Where core has shifted more than one-fourth the thickness of the shell, compute the strength of column assuming thinnest side to be uniform all around. Columns without open sides or back to have ⅜ inch test hole. Shoes under columns planed on top.

Sec. 114. Party wall columns to be not less in thickness than the party wall; and not less in depth than the thickness of the wall to be supported above.

Sec. 115. Plates between joints of open back columns.

Sec. 129. Cast iron columns not to be painted before inspection.

Steel and Wrought Iron.

Sec. 21. Steel and wrought iron to be of good quality.

Sec. 111. Steel and wrought iron columns; workmanship, least thickness of metal, etc.

Sec. 116. Steel and iron girders; spacing and size of rivets; use of web stiffeners.

Sec. 120. Rolled steel and iron beams to be free from defects.

Framing.

Sec. 120. Beams resting on girders to be bolted to same.

Sec. 122. All iron work to be properly framed and connected together and to the walls. Defective work.

Sec. 123. Good riveting required.

Sec. 125. Trusses to be rigid and well braced.

Sec. 126. All connections in trusses to be riveted.

Separators, Lintels, Anchors, Tie Rods, Templates, Etc.

Sec. 41. Exterior piers to be anchored to steel frames at each tier.

Sec. 42. Iron lintels to have not less than five inches bearing at each end. Stone or metal templates not required for spans less than six feet.

Sec. 61. Wooden posts to have iron cap and base plates.

Sec. 117. Iron beams used in pairs to form a girder to have separators not more than 5 ft. apart. Beams 12 in. and over to have 2 bolts in each separator.

Sec. 118. Cast lintels to span not more than 16 ft. and to be not less than ¾-inch thick all over.

Sec. 119. Cast iron templates or 10 in. stone templates to be used under girders over 12 ft. long resting on brick. For spans less than 12 ft. the stone template may be 5 in. thick.

Sec. 120. Tie rods; spacing not to exceed 8 feet; spacing not to exceed eight times the depth of the beams.

Sec. 121. Templates to be sufficiently large to avoid excessive pressure on masonry.

Painting.

Sec. 129. Iron or steel under water to be enclosed in concrete. All structural metal work shall be cleaned and painted one coat of paint. After erection all work shall be painted at least one additional coat. Cast iron columns not to be painted before inspection.

CHAPTER XIX.

Special Regulations of the Bureau of Buildings.

It often happens that the Building Code does not cover specifically certain kinds of work going on within the limits of a borough. Any additional regulations may be established within a borough by the Superintendent. Violating such regulations is just as serious as violating any provisions of the Code.

Regulations made by the Superintendent are generally printed for distribution. Following are examples of special rules and regulations in force in Manhattan Borough:

PROJECTIONS BEYOND BUILDING LINE.

(Bulletin No. 1, January 3, 1911.)

NOTICE IS HEREBY GIVEN that on and after this date no building plans not already on file in this department, or in the Tenement House Department, will be approved by the Bureau of Buildings for the Borough of Manhattan which provide for an encroachment by any part of the building beyond the building or lot lines at any point less than ten feet above the curb grade, except that:

(a) Non-supporting columns or pilasters, including their mouldings and bases, may project not more than two and one-half per cent. of the width of the street, and in no case more than two feet beyond the building line.

(b) Steps leading up or down at entrances, and included between ornamental columns, pilasters or check pieces at least three feet high, at the sides of such entrances, provided they do not exceed, together or separately, one-fifth of the width of the lot, may project not more than two and one-half per cent. of the width of the street, and in no case more than eighteen inches beyond the building line.

(c) Mouldings or ornamentations of a decorative character, and base courses, including the water-table, not exceeding five feet in height above the curb grade, may project not more than one and one-fourth per cent. of the width of the street, and in no case more than ten inches beyond the building line.

(d) Rustications may project not more than four inches beyond the building line.

Marquises or awnings, supported wholly from the building, will be permitted where they do not extend more than two and one-half feet on either side of an entrance, provided they are constructed of iron and glass or other incombustible material, and are properly drained.

ELECTRIC SIGNS.

(Amended ordinance of the Board of Aldermen, approved by the Mayor, July 24, 1912.)

Section 1. Any letter, word, model, sign, device or representation used in the nature of an advertisement, announcement or direction illuminated by electricity, erected on any building in the City of New York, and extending beyond the building line, shall be deemed to be an electric sign.

Section 2. Electric signs are permitted in the City of New York and the City Clerk is empowered to issue licenses therefor under the following terms and conditions, to wit:

A. Upon the payment by the applicant of an annual license fee of ten cents for each square foot of sign space or part of square foot of such sign space displayed on such electric sign, to be computed and collected by the City Clerk of the City of New York. The square feet of sign space on one side of an electric sign, however, shall be deemed to be the entire number of square feet of sign space for the purpose of computing the license fee herein referred to and required to be paid.

B. That no electric sign shall extend more than eight feet from the building line in the City of New York.

C. That no electric sign shall be less than ten feet in the clear above the level of the sidewalk beneath such sign.

D. That electric signs shall be constructed entirely of metal or other incombustible material, except the insulation thereof, including the uprights, supports and braces for the same, and shall be properly and firmly attached to the building, and shall be so constructed as not to be or become dangerous.

E. That no electric sign shall be so erected as to obstruct or prevent free ingress and egress to any window or fire escape on any building in the City of New York.

F. That prior to the erection of any electric sign in the City of New York, a license therefor must be obtained from the Clerk of the City of New York, and before the issuance of any license herein by said City Clerk for the said electric

sign, the applicant shall first file with the Superintendent of Buildings of the borough wherein the said electric sign is to be erected, plans and statements of the proposed electric sign and method of attachment of same to the building.

MOVING PICTURE BOOTHS.

(Bulletin 32, 1911.)

Booths enclosing cinematograph or similar apparatus.

Such booths shall be at least seven feet in height. If one machine is to be operated in such booth the floor space shall not be less than forty-eight square feet. If more than one machine is to be operated therein, an additional twenty-four square feet shall be provided for each such additional machine. Such booths shall be constructed with a framework of iron angles not less than one and one-quarter inches by one and one-quarter inches by three-sixteenths of an inch thick, the adjacent iron members being joined firmly with angle plates of iron. The iron members of the framework shall be spaced not more than four feet apart on the sides and not more than three feet apart on the front and back and top of such booth. The asbestos board shall completely cover the sides, top and all joints of such booth. The sheets shall be at least one-quarter of an inch in thickness and shall be securely attached to the iron framework by means of iron bolts or rivets. The floor space occupied by the booth shall also be covered with asbestos board not less than three-eighths of an inch in thickness. There shall be provided for the booth a door not less than two feet wide and six feet high, consisting of an angle iron frame covered with sheets of asbestos board one-quarter of an inch thick, and attached to the framework of the booth by hinges, in such a manner that the door shall be kept closed at all times when not used for ingress or egress. The operating windows, one for each machine to be operated therein and one for the operator thereof, shall be no larger than reasonably necessary to secure the desired service, and shutters of asbestos board shall be provided for each window. When the windows are open, the shutters shall be so suspended and arranged that they will automatically close the window openings, upon the operating of some suitable fusible or mechanical releasing device.

No apparatus for projecting moving pictures shall be operated until a certificate has been obtained from the Superintendent of Buildings that the booth enclosing the same is in accordance with the law.

CHAPTER XX.

Extracts from the State Labor Law and the Sanitary Code.

EXTRACTS FROM THE STATE LABOR LAWS.

Following are some of the main provisions of the State labor laws, which are partly enforced by the inspectors of the Bureau of Buildings. Violations of these provisions are reported to the Superintendent of Buildings, who in turn notifies the State Labor Bureau. This last authority prosecutes all labor law violations.

Chapter 36 of the Laws of 1909, constituting Chapter 31 of the Consolidated Laws, as amended to October 1, 1911.

Scaffolding for Use of Employees.

Sec. 18. A person employing or directing another to perform labor of any kind in the erection, repairing, altering or painting of a house, building or structure shall not furnish or erect, or cause to be furnished or erected for the performance of such labor, scaffolding, hoists, stays, ladders or other mechanical contrivances which are unsafe, unsuitable or improper, and which are not so constructed, placed and operated as to give proper protection to the life and limb of a person so employed or engaged.

Scaffolding or staging swung or suspended from an overhead support, or erected with stationary supports, more than twenty feet from the ground or floor, except scaffolding wholly within the interior of a building and which covers the entire floor space of any room therein, shall have a safety rail of suitable material, properly bolted, secured and braced, rising at least thirty-four inches above the floor or main portions of such scaffolding or staging and extending along the entire length of the outside and the ends thereof, with such openings as may be necessary for the delivery of materials, and properly attached thereto, and such scaffolding or staging shall be so fastened as to prevent the same from swaying from the building or structure.

Inspection of Scaffolding, Ropes, Blocks, Pulleys and Tackles in Cities.

Sec. 19. Whenever complaint is made to the Commissioner of Labor that the scaffolding or the slings, hangers, blocks, pulleys, stays, braces, ladders, irons or ropes of any swinging or stationary scaffolding used in the construction, alteration, repairing, painting, cleaning or pointing of buildings within the limits of a city are unsafe or liable to prove dangerous to the life or limb of any person, such Commissioner of Labor shall immediately cause an inspection to be made of such scaffolding, or the slings, hangers, blocks, pulleys, stays, braces, ladders, irons or other parts connected therewith. If, after examination, such scaffolding or any of such parts is found to be dangerous to life or limb, the Commissioner of Labor shall prohibit the use thereof, and require the same to be altered and reconstructed so as to avoid such danger. The Commissioner of Labor or deputy factory inspector making the examination shall attach a certificate to the scaffolding, or the slings, hangers, irons, ropes or other parts thereof, examined by him, stating that he has made such examination, and that he has found it safe or unsafe, as the case may be. If he declares it unsafe, he shall at once, in writing, notify the person responsible for its erection of the fact, and warn him against the use thereof. * * * All swinging and stationary scaffolding shall be so constructed as to bear four times the maximum weight required to be dependent therefrom or placed thereon when in use, and not more than four men shall be allowed on any swinging scaffolding at one time.

Protection of Persons Employed on Buildings in Cities.

Sec. 20. All contractors and owners, when constructing buildings in cities, where the plans and specifications require the floors to be arched between the beams thereof, or where the floors or filling in between the floors are of fireproof material or brickwork, shall complete the flooring or filling in as the building progresses, to not less than within three tiers of beams below that on which the ironwork is being erected. If the plans and specifications of such buildings do not require filling in between the beams of floors with brick or fireproof material all contractors for carpenter work, in the course of construction, shall lay the under-flooring thereof on each story as the building progresses, to not less than within two stories below the one to which such building has been erected.

Where double floors are not to be used, such contractor shall keep planked over the floor two stories below the story where the work is being performed. If the floor beams are of iron or steel, the contractors for the iron or steel work of buildings in course of construction or the owners of such buildings shall thoroughly plank over the entire tier of iron or steel beams on which the structural iron or steel work is being erected, except such spaces as may be reasonably required for the proper construction of such iron or steel work, and for the raising or lowering of materials to be used in the construction of such building, or such spaces as may be designated by the plans and specifications for stairways and elevator shafts. If elevators, elevating machines or hod-hoisting apparatus are used within a building in the course of construction, for the purpose of lifting materials to be used in such construction, the contractors or owners shall cause the shafts or openings in each floor to be enclosed or fenced in on all sides by a barrier at least eight feet in height, except on two sides which may be used for taking off and putting on materials, and those sides shall be guarded by an adjustable barrier not less than three nor more than four feet from the floor and not less than two feet from the edge of such shaft or opening. If a building in course of construction is five stories or more in height, no lumber or timber needed for such construction shall be hoisted or lifted on the outside of such building. The chief officer in any city charged with the enforcement of the building laws of such city and the Commissioner of Labor are hereby charged with enforcing the provisions of this section and sections 18 and 19, and said chief officer in any city charged with the enforcement of the building laws of such city shall have the same powers for the enforcement of these sections as are vested in the Commissioner of Labor.

Accidents to be Reported.

Sec. 20a. The person in charge of any building, construction, excavating or engineering work of any description, including the work of repair, alteration, painting or renovating, shall keep a correct record of all deaths, accidents or injuries sustained by any person working thereon, in such form as may be required by the Commissioner of Labor. Such record shall be open to the inspection of the Commissioner of Labor and a copy thereof shall be furnished to the said Commissioner on demand. Within forty-eight hours after the time of the accident, death or injury, a report thereof shall be made

in writing to the Commissioner of Labor, stating as fully as possible the cause of the death or injury, and the place where the injured person has been sent, with such other or further information relative thereto as may be required by the said Commissioner, who may investigate the causes thereof and require such precautions to be taken as will prevent the recurrence of similar happenings.

Penalties for Violation of Foregoing Provisions of the Labor Law: Penal Law, Article 120, Laws 1909, Chapter 88.

Negligently Furnishing Insecure Scaffolding.

Sec. 1276. A person or corporation employing or directing another to do or perform any labor in the erection, repairing, altering or painting, any house, building or structure within the State, who knowingly or negligently furnishes or erects or causes to be furnished or erected for the performance of such labor, unsafe, unsuitable or improper scaffolding, hoists, stays, ladders or other mechanical contrivances; or who hinders or obstructs any officer detailed to inspect the same, destroys or defaces any notice posted thereon, or permits the use thereof after the same has been declared unsafe by such officer, is guilty of a misdemeanor.

Neglect to Complete or Plank Floors of Buildings Constructed in Cities.

Sec. 1277. A person constructing a building in a city, as owner or contractor, who violates the provisions of Article 2 of the Labor Law, relating to the completing or laying of floors, or the planking of such floors or tiers of beams as the work of construction progresses, is guilty of misdemeanor, and upon conviction therefor shall be punished by a fine for each offense of not less than twenty-five nor more than two hundred dollars.

EXTRACTS FROM THE SANITARY CODE.

In some instances where the Building Code does not specifically cover defective and unsafe work, Sec. 8 of the ordinance known as the Sanitary Code may also be enforced by the Superintendent of Buildings. The Sanitary Code is based on Chapter XIX. of the Laws of 1897 and Chapter XIX. of the Laws of 1901. Section 8 of this Code is a most sweeping provision, covering all defective work. This section follows:

Misfeasance and Nonfeasance.

Sec. 8. No person shall carelessly or negligently do or devise or contribute to the doing of any act or thing dangerous to the life, or detrimental to the health of any human being; nor shall any person knowingly do or advise or contribute to the doing of any such act or thing (not actually authorized by law), except with justifiable motives, and for adequate reasons; nor shall any person omit to do any act, or to take any precaution, reasonable and proper, to prevent or remove danger or detriment to the life or health or any human being.

CHAPTER XXI.

Extracts from the Rules and Regulations of the Bureau of Buildings.

The following extracts are given here for the benefit of candidates for the positions of Building Inspectors. From these rules and regulations a careful reader can get an approximate idea of the nature of the work performed by Inspectors.

In a well organized Bureau of Buildings, as i. e. the Manhattan Bureau of Buildings, there are at least six kinds of inspectors, namely:

Inspectors of iron and steel construction.

Inspectors of masonry and carpentry.

District inspectors.

Inspectors of plumbing.

Inspectors of elevators.

Inspectors of plastering.

Each inspector has a definite district assigned to him.

The district inspectors look after small alterations for which a permit is issued in a form known as "Slip Application." They also report cases where work is started without a permit, and unsafe cases.

Inspectors of masonry and carpentry have charge of all new buildings and main alterations, for which a regular permit is issued. They also take care of demolitions and file unsafes on adjoining premises when necessary.

Both district and masonry inspectors report to the chief inspector about all iron work requiring inspection. These reports are made in writing upon blanks furnished for the purpose and are turned over to the iron inspectors.

It may also be noted that there is nothing in the rules that prevents an inspector from doing work for private concerns after the office hours. Nevertheless, it is taken as granted that an inspector working after hours with a builder will not be qualified to pass an independent judgment on jobs belonging to the same builder.

While inspectors should give during their regular inspection work intelligent advice on difficult points of construction whenever possible, they should consider as a matter of honor and of personal integrity demanded by the dignity of their official position, not to accept any outside work, or anything else that might impair their judgment in making inspections of building work.

EXTRACTS

FROM THE RULES AND REGULATIONS OF THE BUREAU OF BUILDINGS

of

THE CITY OF NEW YORK

For the Borough of Manhattan.

I. Assistant Superintendent of Buildings. Duties.

The Assistant Superintendent of Buildings shall perform such duties as may be imposed upon him by the Superintendent of Buildings.

II. Chief Inspector. Duties, Responsibility, Etc.

The Chief Inspector of Buildings shall, when so authorized, be charged with the same duties as the Superintendent of Buildings during his absence, and with the performance of such work as the Superintendent may prescribe.

The Chief Inspector of Buildings shall be directly responsible to the Superintendent for the proper conduct and management of the Bureau, and he is charged with the prompt execution and enforcement of all laws, rules, regulations and orders of the Superintendent.

III. Inspectors. Hours of Reporting, Etc.

Inspectors will report to the Chief Inspector of Buildings, at the office of the Department, at 8:30 A. M. each day, except Sundays or legal holidays, unless otherwise ordered, prepared to hand in the reports of the operations of the previous day in their respective districts, and upon receiving such instructions as may be given them will immediately proceed to the performance of duty within their respective districts, or to such special duty as may be assigned them.

Leaving District.

Unless by permission, no Inspector will leave his district during working hours.

Daily Journal.

Each Inspector is required to keep a journal, which must be signed by the Inspector at the completion of the day's

work, in which must be entered a list of the papers received and turned in, the time of leaving the office, and the buildings visited each day, whether new buildings or buildings being altered, unsafe buildings or buildings requiring fire-escapes or proper means of exit. The time of visit and condition of the work must be noted in the journal, which must be signed by the Inspector.

Books for the purpose will be furnished by the Bureau, and will be the property of the Bureau, and must be surrendered by the Inspector when leaving the Bureau.

Reports must be in writing on the forms provided by the Bureau, and be promptly presented.

Violations, Etc.

In cases of violations, the nature thereof must be clearly stated, as well as the number of the section or sections of the law violated, and, as the forms are printed and easily understood, it is expected that there will be no necessity for returning them to the Inspector for correction. No reports will be received unless properly made and written in ink. Any Inspector who does not feel qualified to properly make a report of a violation, fire-escape or unsafe building, etc., will receive instructions upon application.

Copies of the Law.

The Inspectors will be provided with copies of the laws relating to the construction of buildings in this city, and it is expected that they will become thoroughly familiar with the provisions of the same.

Daily Inspections.

All buildings in process of erection or alteration in the respective districts must be examined daily to see if they are being altered or erected in conformity to the laws and according to the terms and conditions of the plans and specifications for said construction or alteration, and also the terms and conditions of the plans and specifications for plumbing and drainage, as submitted and approved.

Violations of the Law—Bad Materials, Etc.

Should the Inspector find a building or buildings being erected or altered without permit, he will so report and prefer a complaint against the persons so violating the law. Build-

ings in which bad materials are used will be reported, and the Inspector will state in his report how much, if any, of the wall or walls in which such materials were used must be taken down.

Should the parties using bad materials fail to cause the removal of the same within twenty-four hours, they must be reported by the Inspector for prosecution.

Complaints.

All complaints referred to the Inspectors must be examined and reported on immediately on the form provided for that purpose.

False Reports.

Making false reports, or failing to comply with these rules and regulations on the part of any Inspector will be deemed sufficient ground for his removal.

Ironwork.

Inspectors are required to the report to the Chief Inspector what ironwork is to be used on any and every building in their districts; also when the same is ready for inspection, and make a violation case when any ironwork is being used before said inspection and approval.

Prompt Report of Violations.

Should an inspector find a building or buildings being erected or altered with unlawful construction, with or without a permit, he will so report as soon as possible, that the Superintendent may take proper action to prevent the same.

Badge of Office.

Inspectors are required, while on duty, to wear on the left side of their outer garment, and exposed to view, their badge of office, and any Inspector who shall loan his official badge to any person whatever will be dismissed from the service of the Bureau.

Hours of Duty.

Inspectors are expected to be on duty from 8:30 A. M. to 5 P. M., except on Saturdays, when they shall be on duty

from 8:30 A. M. to 12 M., and except when otherwise ordered by the Superintendent of Buildings.

Entries in Daily Journals.

All visitations to new buildings and alterations to buildings and all other matters entered in Inspectors' journals must be entered with the "Sun Copying Pencil," thus making such entries indelible. Any entries made in any other manner will be deemed sufficient grounds for the immediate dismissal of the offender. Said pencils may be obtained on application.

Violations of the Law.

All violations of every nature reported by the several Inspectors must be from a personal investigation, and they must be personally acquainted with all the facts in each case, and not rely on information given by others.

Entries in Note-Books.

Inspectors are required to state, in the entry in their note-books, of visitations to buildings, the floor or floors they examined at the time of such visitations.

Inspections.

Any Inspector of Plumbing making an inspection of plumbing, and any Special, Building, Iron or Elevator Inspector making any inspection, upon a request, either verbal or contained in any communication, not received from the Bureau direct, will at once be dismissed.

All requests, verbal or written, for such inspections, received from any other source, must be forwarded to the Superintendent of Buildings at once.

Taking Papers From Office.

No official paper may be taken from the office without permission, excepting Inspectors' copies.

Official Communications.

The officers and employees of this Bureau are forbidden to write letters of endorsement or recommendation of any form of construction, mechanism or device which may be used in any part of a building, to owners, manufacturers,

patentees or other interested persons. The penalty for a violation of this rule will be instant dismissal.

All official communications, or communications in any manner relating to the official business of the Bureau, whether verbal or written, shall be made through the Superintendent of Buildings.

Private Interests.

While in the service of this Bureau its officers and subordinates shall not make use of or apply any portion of the time they may be required to devote to the performance of the duties devolved upon them, or any information they may have acquired therein, or any authority or power with which they may be clothed, in or for the furtherance of any private or corporate interests or purposes whatever.

Physical Disability.

It is made the duty of all employees, in case of physical or other disability preventing their prompt appearance for duty at the required time, to report that fact to their immediate superior in time to enable the substitution of another to perform their duties, if necessary.

Luncheon.

One hour shall be allowed to each employee for noonday luncheon or dinner in such manner as shall not interfere with the business of the Bureau.

Business Transacted Confidential.

The public business transacted in and the records of the office shall be treated as strictly confidential by the several officers and employees of the Bureau, and shall not be communicated except as may be directed by the Superintendent of Buildings.

Taking Applications From Office.

Under no circumstances will any application or drawing for the erection or alteration of any building be allowed to be taken from this office.

Letters to Employees.

All letters addressed to employees relative to business connected with this Bureau must be referred to the Super-

intendent of Buildings before any action is taken thereon by the parties to whom the same are addressed.

Car-Fare Bills.

All car-fare bills not handed in by the 4th day of the month, at the latest, will not be forwarded to the Finance Department for payment.

Improper Use of Official Badge.

Any and all employees of this Bureau who shall make use of his or their position or official badge for the purpose of obtaining admission for himself or others to any place of amusement during the time of performance, or for obtaining tickets for the same, will be fined or dismissed at the discretion of the Superintendent of Buildings.

CHAPTER XXII.

Reports.

GENERAL REMARKS. The inspection of premises by a municipal inspector is an official act and is permanently recorded. This record may be an entry in an official note book or journal, or may be represented into greater details by means of violations, unsafes, or by special reports.

The Journal, or individual district note book is city property. Brief reports are here entered by the inspector on the premises, and in order to make these reports permanent, either ink or indelible pencil may be used. A journal report takes generally one or two lines, and consists of the following information:

The official number of the permit to build, classified as N. B. (new buildings) or Alt. (alterations). i. e. N. B. 73-12 means the 73rd set of plans for new buildings approved by the Bureau of Buildings of a certain Borough in year 1912.

The location of the premises inspected.

The time of arrival at, and the departure of the inspector from the given premises.

An entry of number and kind of materials approved.

An inspection report indicating in all cases the actual condition of the work, orders issued by the inspector to the builders, and any other items of special interest.

A day's entries in an iron inspector's Journal will look something like page 173.

The number of daily inspections, for an iron inspector, is generally between 12 and 20 and depends largely upon the nature of the work and the proximity of the jobs to one another and to the main office. The average time for inspections for a number of inspectors in a given day in 1911 was 20 minutes for a new building and 10 minutes for an alteration.

Violation Reports are of various kinds, depending upon the nature of the violation committed. All violation reports are made out on printed violation forms. A complete violation will read like the following:

March 7th, 1913.

To the Superintendent of Buildings for the Borough of Manhattan:

Sir:

I respectfully report that, on March 6th, I examined the premises and building situated on the front of the lot on the

THURSDAY					APRIL 10th, 1913.	
New Bldgs.	Alterations	LOCATION	Arr.	Lv.	Approved	REMARKS.
		Bureau of Buildings	8.30	9.30		
73–12		S. W. Cor. 25th St. & 5th Ave.	9.40	10.05	beams 28	Setting grillage beams; inspected bolts and separators. Call up plans.
	218–11	1300 B'way at 26th St.	10.10	10.40	columns 45	Erecting 4th tier beams; ordered 50% of temporary bolts put in all column splices.
98–13		28 W. 26th St.	10.45	11.15		Riveting on 6th tier; inspected riveting. Ordered 26 loose rivets on 4th tier cut out and replaced.
126–12		45 W. 26th St.	11.20	11.35	cast iron 4 cols.	Painting on 5th tier; quality of paint is not satisfactory. File violation.
134–13		48-54 W. 27th St.	11.40	12.00	girders 2	6th tier set; all tiers above 2nd are not filled in. File floor arch violation.
		Lunch	12.00	1.00		
	316–13	112 W. 27th St.	1.00	1.40	struts 4	Erecting exterior stairways at 11th tier; inspected anchorage and bolting.
	38–12	386 Sixth Ave. at 27th St.	1.45	2.20		All iron set; ordered defective separator bolts on 5th tier replaced by ¾ in. bolts.
212–13		418 Sixth Ave. at 28th St.	2.25	3.05	beams 240	Iron men not working; ordered all beams painted.
246–15		N. W. Cor. 28th St. & 8th Ave.	3.15	3.50	columns 120	Setting 16th tier; ordered all connections under derricks fully bolted.
	415–12	S. E. Cor. 34th St. & B'way	3.55	4.15		Inspected pent house on roof; covering up defective connections; will file special report.
386–13		148 W. 34th St.	4.20	4.40	trusses 6	Floor arches completed within three tiers from roof. Dismiss violation.
245–13		256 W. 36th St.	4.45	5.00	bases 10	Inspected and approved ten cast iron bases. Rejected base No. 2 for bad blow holes.

The above reports were made by me on the premises, and are true.

JOHN SMITH, Iron Inspector.

N. side of W. 26th St., commencing about 200 feet from the N. W. corner of 6th Ave. and W. 26th St., and known as No. 126-128 W. 26th St., and find existing thereon a violation of Sections 122-129 of the Building Code, as follows:

In that 8 in. beams on 1st tier West are connected to 20 in. girders by means of defective, loose bolts, insufficient in number, forming weak connections; same being contrary to law. In omitting a field coat of paint after the erection of iron work, same being contrary to law.

Said building being semi-fireproof. Building, cellar and five stories in height, 50 feet front, 50 feet rear, 76 feet deep, and 60 feet high, and occupied or intended to be occupied as stores and lofts, and located in the Borough of aMnhattan, in The City of New York.

Name and address.

Owner, John D. Doe, 65 W. 135th St.

Lessee, Mark Wise, 50 Riverside Drive.

Agent, Same as owner.

Architect, Geo. Tillmann, 1133 Broadway.

Gen'l Contractor, Industrial Constr. Co., 60 Wall St.

Iron and S. Contractor, Stark Iron Works, 356 Claremont Ave., Bronx.

PLAN NO.	New Building, 236	1912
	Alteration	191.
	Slip Application	191.
	No Construction	191.

What immediate action (if any) is necessary? None.

(Signed) H. Butler.

(Title) Inspector Iron and Steel.

It is seen that each violation report gives the official plan or permit number for the job, the location, the section of the code or other laws or ordinances that have been violated, as well as a complete specification of the violation committed. This specification must be brief, definite and must give such a description of the defective work mentioned in it, that any person could locate this work without any further aid from the part of the inspector. The specification must not be ambiguous and must be such that the City's Corporation Counsel shall be able to prosecute the case, should it come up before the court.

All violations must contain a description of the building as to size, height, number of stories, as well as the names of the owner, architect, builder and contractors.

All violations must be reported as soon as discovered. An inspector, however, is not expected to file violations for un-

7. Sec. 4. In erecting a steel flue 7 ft. diam. and ¼ in. thick, running from cellar to roof, same not being shown in the approved plans.

8. Sec. 4. In that the frame work of a sky sign is anchored to roof by three ½ in. lag screws to each bent, in place of ten ¾ in. lag screws; in that rails supporting the sign proper are made of wood, instead of steel; in that bents are spaced about seven feet apart instead of 5′-6″, same being contrary to approved plans.

9. Sec. 4. In using 6 in. x 4 in. angles instead of 6 in. x 6 in. angles in supporting terra-cotta partitions around elevator shaft.

9. Sec. 4. In using one ½ in. bolt in each end of angle braces of sky sign, instead of two ½ in. bolts, same being contrary to approved plans.

11. Sec. 4. In erecting winding stairs near the north west corner of the building, in place of a straight flight of stairs, contrary to approved plans.

12. Sec. 4. Erecting two bonded brick piers 3 feet sq. each in place of 12 in. sq. cast iron columns; erecting brick arches between said piers on the second tier in place of steel girders.

13. Sec. 4. In using two 12 in. wrough iron beams at the 2nd tier front in place of two 12 in. steel beams.

14. Sec. 4. In erecting four 8x8x¾ in. cast iron columns at the rear of first tier instead of four 8x12x1 in. cast iron columns.

15. Sec. 4. In erecting 6 in. channel beams laid flat instead of laying same on edge.

16. Sec. 4. Supporting stair upright by means of expansion bolts in place of ¾ in. through wall anchors with washers on the inside of the walls. Omitting two 12 in. channel beams on first tier west, contrary to approved plans.

17. Sec. 4. Sky sign braces of single vs. double 2x2 angles; in that the sky sign area is larger than 10x26 ft.

18. Sec. 4. Covering with full metal a sky sign framing intended to be used for open letters.

19. Sec. 4. In anchoring a marquise to wood construction instead of anchoring same to 10 in. steel beams at the second tier. Anchoring wall hangers by means of expansion bolts instead of through bolts with washers.

finished work, like for unset iron, or for work that might be in violation of the law only after such work has been completed.

Committing a violation carries with it a fine of $50. Not complying with the violation within ten days from the time papers were served, may incur a maximum penalty of $250, when the case is taken to court and prosecuted. When good excuse is shown, however, the Superintendent may return this fine.

Following are examples of common violation specifications, used in connection with the printed violation blanks before mentioned. In each case is given only the section or sections of the Law or the Building Code, which have been violated, and the specified violation expressed in a suitable form. Date, names and location are left out.

VIOLATIONS ON IRON WORK. Over fifty cases of common violations are here given. A careful study of these violations will present to the reader a set of common errors found in structural steel work.

1. Sec. 4. In erecting two 15 in. beams near the N. W. corner of the 5th tier, 3 feet further north of the positions shown in the approved plans.

2. Sec. 4. In erecting a roof sign near the S. W. corner of the main roof, no permit to build having been issued for same by the Bureau of Buildings.

3. Sec. 4. In omitting tie rods in the second tier west; omitting bearing plates and wall anchors in sidewalk beams; omitting two 7 in. beams in the roof of the pent house and setting the remaining beams 56 in. on centres instead of 48 in. on centres; all these being contrary to approved plans.

4. Sec. 4. In omitting one upright brace in a sky sgin erected on the main roof; in omiting gusset plates at intersection of diagonal members; in using 2x2x¼ angles for uprights and braces in place of 2½x2½x¼ in. angles; all these being contrary to approved plans.

5. Sec. 4. Erecting 9x¼ in. steel stringers in an exterior stairway at the rear of the building, in place of stringers built of one 10x¼ in. steel plate and two 1¼x1¼ angles, same being contrary to approved plans.

6. Sec. 4. In that the framing supporting a roof sign at the front of the building is not anchored to side walls by means of steel straps and expansion bolts, same being contrary to approved plans.

20. Sec. 4. In erecting a 12x8 ft. marquise on the north side of the building, same not being shown on the approved plans.

21. Sec. 4. In erecting four 8 in. I-beams to form a vault under the sidewalk, same being contrary to approved plans.

22. Sec. 4. In erecting a roof framing consisting of 7 in. I-beams 6 ft. on centres instead of 4 in. T irons 2 feet on centres.

23. Sec. 4. In using Bethlehem beams and columns instead of Standard beams and built up columns made of steel plates and angles riveted together.

24. Sec. 4. In erecting an iron stairway in cellar and a gravity tank on the roof, both on the west side of the building instead of east.

25. Sec. 4. In omitting all steel beams above fire proof passage at the east of second tier.

26. Sec. 4-117. In erecting grillages on the north side under all wall columns, consisting of five 20 in. 80 pounds I-beams in place of five 20 in. 90 pounds I-beams; in that grillage beams are provided with separators further apart than five feet on centres; in erecting 15 in. channels of less weight than 40 pounds per foot on the east side of 5th tier; all these being contrary to approved plans and contrary to law.

27. Sec. 4-122. In erecting grillages consisting of 12 in. -20½ pound channels under front columns, where plans call for 10 in.-20 pound channels, the webs of 12 in. channels being thinner than the webs of 10 in.-20 pounds channels (and therefore more likely to cripple under the load). In omitting bolts in connections of column footings to grillages.

28. Sec. 4-122. In using round cast iron columns in place of square cast iron columns on 1st tier; in that the rear columns on 1st tier are set eccentrically upon the grillage and are out of plumb; in omitting 4x4 tie-angles between 2nd tier front columns.

29. Sec. 4-122. In erecting 8 in. x 1 in. cast iron column on 1st tier front in place of 9 in. x 1 in. cast iron column; in not bolting beams to cast iron columns; in using loose and defective bolts on the second tier rear.

30. Sec. 4-122-129. Erecting single 20 in. beams instead of double girders made of two 18 in. beams, between all columns on south side of all floors to roof inclusive; omitting bolts in connection of girders to wall columns on first six tiers

west; in not painting floor beams with a second coat of paint after erection; in not painting columns next to N. party wall on all four faces; in omitting pier angles on second tier S. All these being contrary to law.

31. Sec. 4-122-129. In that the sky sign on main roof front is not supported on sleepers laid flat on roof, but rests on wood cornice 2′-4″ beyond the face of the building; in omitting horizontal bracing; in that the connections between front of sign and face of wall have been omitted; in that the sign braces are not properly lag-screwed to main roof; in providing an additional rail and an extra section of steel framing on top of sign thus increasing the wind exposed area contrary to approved plans; in that two cross braces on each bent are omitted; in that gusset plates are omitted; in that face uprights are made of 2½x2x¼ in. angles instead of 2½x2½x 5/16 in. angles; in using ⅜ in. diameter bolts instead of ½ in. diameter bolts in all bolted connections; in that the iron used in the two east bents is unpainted and in a corroded condition.

32. Sec. 60. Omitting iron straps required to anchor wall girders in store front to wooden floor beams of the second tier.

33. Sec. 111. In that the lower ends of columns 3-5-9-on 4th tier rear are not faced to a plane surface at right angles to the axis of the column but are sawed to an uneven surface and bear unevenly on base plates of columns below.

34. Sec. 112. In that cast iron columns at the 2nd tier are not provided with four ¾ in. bolts in each splice.

35. Sec. 112-129. In painting cast iron columns before inspection; in not providing ⅜ in. test holes in same.

36. Sec. 112. In erecting on the first tier front, round cast iron columns, which are three feet longer than shown in the approved plans, thus causing the unsupported length of these columns to exceed twenty diameters; same being contrary to law.

37. Sec. 117. In using pipe separators instead of cast iron separators in between double 12 in. girders on the 10th tier east, contrary to approved plans.

38. Sec. 117-121-122. In that 12 in. girders are not securely bolted to 15 in. beams on first tier, the bolts being not tightened; in omitting templates under wall bearing ends of steel beams on 4th tier rear; in that two 15 in. beams on 4th tier west, have insufficient bearing on walls; omitting separators between steel beams at second tier front; in that separators between 1st tier double beams on west side are over five feet on centres.

39. Sec. 11. In that tie rods in the first tier of steel beams are not properly set, are of improper lengths and are loose; same being defective work contrary to law.

40. Sec. 122. In that platforms on exterior stairway at the rear of the building are not properly secured in place against displacement; in that hand rails have no brackets and lack rigidity; all these being defective work contrary to law.

41. Sec. 122. In that 6 in. x 6 in. upright angles in the rear exterior stairways do not bear at splices.

42. Sec. 122. In that bridle irons supporting the wood girders on 3rd and 4th tier are weak and defective.

43. Sec. 122. In that girders supporting floor beams at 8th tier are not strapped and bolted together and to the beams.

44. Sec. 122. In making connections of 12 in. to 15 in. beams on the third tier by means of ¾ in. bolts passing through burnt holes; in using slotted holes in standard connections in place of 13/16 in. round holes.

45. Sec. 11. In that the iron grating over the area on the 5th Ave. side is not properly supported and secured.

46. Sec. 122-129. Omitting a field coat of paint after the erection of all iron work in the pent house framing; using loose ½ in. diam. bolts in 13/16 in. holes without providing washers; omitting bolts in connections of 4x4 angles to 12 in. channels on the S. side of the pent house; using loose bolts and bolts without nuts in connections of T. irons to pent house roof beams; all these being defective work contrary to law.

47. Sec. 122-140. In that the stiffeners used in girder to column connections for wind bracing do not bear on ends, causing lack of rigidity against wind pressure; same being defective work contrary to law.

48. Sec. 129. In using unpainted uprights and stringers in the exterior iron stairway at the rear of the building, same being contrary to law.

49. Sec. 129. In erecting unpainted iron floor beams and columns; in omitting one coat of paint after erection.

50. Sec. 131. In overloading steel floor beams on first tier with construction material causing injury to connections and creating a dangerous condition.

51. Sec. 140. In that the connections of columns and beams supporting the roof tank on the north side of the roof lack rigidity against wind pressure, the braces provided at present being insufficient.

Dismissing Violations. As soon as a violation has been reported, the inspector will usually re-examine the premises at frequent intervals to ascertain whether or not the law has been complied with within ten days from the date of the violation, and whenever possible the exact date of completion of the work should be entered in the journal.

When the law is no longer being violated, the inspector recommends the case to the Superintendent for dismissal. The inspector cannot dismiss a violation. He can only recommend it for dismissal.

Special Reports. These reports are used in all cases when the inspector thinks it is necessary to call the attention of the Superintendent to any unusual or dangerous conditions. Special reports are used to describe collapses, accidents to men and structures, defective or missing safeguards required by law, and defective methods of erection. They are also used in answering letters or complaints from citizens, in reporting results of special examinations and in notifying the Superintendent that defective work specified in a previous violation is about to be covered or bricked in.

Special reports are also made when alterations will temporarily block fire exists, etc. All special reports must be addressed to the Superintendent and must contain the location, date of letter or complaint answered—if any; the number of the violation pending, if any; then the subject matter of the report and finally the signature of the inspector.

Following are several reports, relating to common occurrences in actual building work:

1. A citizen complains to the Superintendent of Buildings that the new 12 story building under construction and adjoining his property has too many open tiers. The citizen thinks that the wind may blow down the new structure and cause untold damages to his property. The inspector receives the letter through the Superintendent and after investigating conditions, he reports as follows:

New York City, Jan. 15, 1913.

Premises: 26 W. 68th St.
In Re: N. B. 1386 of 1913, and Letter of January 13th from John Dobbs, 23 W. 23rd St., City.
Violation: None.
Examined: Jan. 14th, 1913.

Richard Johnson, Esq.,
Superintendent of Buildings.

Sir:

Relative to the above examination I respectfully report as follows:

In the building at 26 W. 68th St. the steel work has been completed up to the 8th tier inclusive, and the 9th and 10th tiers are being set up. Floor arches have been filled in up to and including the 6th tier and wooden centres are being hung on the 7th tier. The building has a base of 50 feet by 90 feet, is of a solid construction and the floor arches are completed as required by law. In addition the new structure is protected on the west side against wind pressure by a tall building and a sufficient number of temporary steel cables are being used, throughout the upper part of the steel frame, to secure the necessary rigidity until the floor aches will be filled in. In my judgment, there is no reason whatever that would justify the above complaint.

Respectfully submitted,

James Wilson,

Inspector of Iron and Steel Construction.

2. During an alteration to an existing loft building a fire escape is temporarily closed by placing building materials on some of the balconies. Write a report and suggest a suitable remedy.

New York City, Feb. 15th, 1913.

Premises: N. W. Cor. 26th St., and 5th Ave.

In re: Alteration No. 1265 of 1913.

Violation: No violation pending.

Examined: Feb. 14th, 1913.

John Smith, Esq.,

Superintendent of Buildings.

Sir:

Relative to above premises I respectfully report as follows:

The building is a 12 story fire proof loft, with all floors occupied by clothing manufacturers. The existing fire escape has been found inadequate and a new fire escape is being built in compliance with a violation of the Bureau of Fire Prevention.

During the erection of the new fire escape, the present fire escaped is being completely blocked with construction materials, thus making it useless as a means of egress in case of fire.

I respectfully suggest that this case be brought to the attention of the Fire Prevention Bureau, for whatever further action it may deem necessary.

Respectfully submitted by

Nicholas Carter,

Inspector Iron and Steel Construction.

3. After ten days from the time a violation is issued, the inspector usually gets an inquiry slip from the violation clerk, to re-examine premises and report. The inspector finds that nothing has been done with regard to the violation and recommends the case to be held for prosecution.

N. Y. City, March 20th, 1913.

Premises: S. E. Cor. 26th St. and B'way.

In re: New Building 763 of 1913.

Violation: No. 3289 of 1913.

Examined: March 19th, 1913.

John Smith, Esq.,
Superintendent of Buildings.

Sir:

Relative to the above premises, I respectfully report as follows:

Nothing has been done to comply with the law. I therefore recommend that the case be sustained.

Respectfully submitted,

Nicholas Carter,
Inspector Iron and Steel Construction.

In the following reports the introduction, title, date and signature are omitted and only the body of the report is given. It is obvious, that a complete report will be of the form shown in the three previous reports.

4. Notice from a citizen is received to the effect that at 56 Water St. a man erects steel beams in front of the house for the purpose of constructing a vault without a permit. The inspector investigates and reports:

Relative to above premises I respectfully report as follows:

Six 8 in. I. beams, four feet on centres and 6 feet long have been erected beyond the building line between the front wall of the building, on one side and an old retaining wall on the street side. The construction is intended to support a vault.

As no permit has been issued by our department for this work, I have filed to-day a violation for erecting iron work without a permit. In the same time I recommend that this case be referred to the Bureau of Highways, for any further action it may deem necessary.

Respectfully submitted by,

5. Short and defective ladders are being used by the iron men in erecting a steel framing for a tall building. The inspector investigates and reports:

Relative to the above premises I respectfully report as follows:

Iron beams and columns are being erected on the 7th and 8th tiers. The ladders used by the iron men consist of 3x10 planks with 2x¾ in. cross pieces every 16 in. These ladders are not tied on top to floor beams as required, and even when fixed in place are extremely dangerous.

I respectfully suggest that the builder be notified by our department to discontinue the use of these ladders.

I also recommend that the State Labor Bureau be notified about this case, for whatever action it may deem necessary.

Respectfully submitted,

6. Report for Dismissal of a Violation.. When a violation has been complied with in all respects, the inspector writes a report to the Superintendent, recommending the case for dismissal. Every item in the original violation must be mention in this report. For instance, to dismiss violation on page 174 the inspector's report will read like this:

Relative to above premises I respectfully report as follows:

The defective connections between 8 in. I. beams and 20 in. girders on the 1st tier west have been fixed, by replacing all defective bolts by new, good bolts; by making all loose parts tight, and by providing four ¾ in. additional bolts in each connection, as directed.

All iron work has been painted a field coat of good paint after erection.

As the law is no longer being violated, I respectfully suggest that this case be dismissed.

Respectfully submitted by,

7. When the construction work becomes dangerous, the inspector must notify the Superintendent as soon as possible to that effect. This is usually done on special (pink) report blanks. For instance:

Relative to above premises I respectfully report as follows:

The structure is a fire proof 10 story loft 50x90 ft. with cast iron columns throughout. The 7th tier of beams is in place. The floor arches have been filled in up to and including the 3rd tier only. Tiers 4-5-6-7 are open. The masonry walls are up to the 2nd tier. Due to heavy west winds and to the exposed location of the premises, the columns near the middle of the structure have a tendency to bulge out from west to east. In fact three lines of columns have been pushed out of plumb nearly ¾ in. in this direction. Efforts are being made

by the iron erectors to bring these columns to a plumb position by means of cables provided with turnbuckles.

In order to avoid dangerous consequences, I respectfully suggest that the iron contractor be notified to discontinue the erection of any iron work above the 7th tier, until the floor arches and the exterior brick walls are completed up to and including the 6th tier.

Respectfully submitted,

8. Defective work is about to be covered before being fixed as required by law. The inspector then reports:

Relative to above premises I respectfully report as follows:

Unpainted iron beams on the 3rd tier rear are being covered up with brick work, same being contrary to law, and contrary to violation 3283 of 1913.

I respectfully suggest that the builder be notified to discontinue laying bricks upon unpainted iron and to remove all brick work as far as necessary to allow for painting.

Respectfully submitted,

9. After the completion of any job where steel work has been used, the iron inspector returns his copy of the application or permit to build, and attaches to it a report like this:

New Building. APPLICATION No. 327 of 1913.

LOCATION: 63 W. 143rd St.

FINAL REPORT OF IRON AND STEEL INSPECTOR.

City of New York, April 16th, 1913.

TO THE SUPERINTENDENT OF BUILDINGS:

I beg to report that the work described in the above entitled application was completed on the 14th day of April, 1913; that all the iron and steel girders, beams and columns are of the size shown in the said application and are properly set; and that the said work was carefully examined by me and found to conform in all other respects to the approved plans and specifications and to the Building Code of the City of New York, except as follows:

Viol. 7263 of 1913, relative to omitting rear exterior stairway is still pending.

Respectfully submitted,

10. We shall close this series of reports by answering the report part of the Civil Service examination of August, 1911. It was required to write a report of not less than two nor

more than three written pages, covering the progress of construction of the steel frame of an important building during a month and including several matters to which an inspector might properly make objection and others requiring positive condemnation. The report may be written as follows:

The Globe Building.

Report for the Month of March, 1913.

To the Chief Engineer of the International Building Construction Co., New York City, N. Y.

Dear Sir:

Relative to the above premises I respectfully report as follows:

Weather conditions during the past month have been mostly unfavorable for our work. During the first half of the month we lost four days due to rainstorms, and towards the end of the month we were prevented from doing work by high winds and snow. In short, we lost one-third of the month due to bad weather.

To make up the time we lost in this way it was necessary to increase the **Forces employed.** The number of riveting gangs was increased from 5 to 7, the painting gang had four men instead of two, and the remainder of the erection force was increased from 24 men to 32 men. In addition a temporary man was assigned to the duties of time-keeper, our regular time-keeper being sick at his home.

Deliveries. During the month the steel beams for 1st, 2nd, 3rd, 4th, 5th, 6th, 9th and 10th tiers, marked respectively tiers A,B,C,D,E,F,J,K, have been delivered; also columns AB, CD, and EF, JK, for tiers 1-2; 3-4; 5-6 and 9-10 have been received. Beams for tiers J and K will not be used till the middle of next month and had to be stored up on the premises. This caused unnecessary rehandling of the materials and the structural shop has been notified to ship in the future all tiers of beams strictly in order of erection and only upon the request of the iron erector.

Storage of Materials. At first no precaution was taken with regard to beams that could not be used for several weeks. The iron erector was therefore instructed to place all these beams on wooden skids, so as not to have the iron in contact with the ground; also these beams were placed so as to shed rain water, and the whole pile was arranged in a manner to require the least possible handling when needed, and so as not

to interfere with the traffic. Red lanterns have been put in at night at each end of the steel pile upon my request, in order to comply with the city ordinances.

Materials Rejected. Following is a complete list of materials rejected during the month, with the reasons therefor and the final action taken in each instance:

March 2nd. Four kegs of ¾-inch rivets, rejected for being 2 inches long instead of 2½ inches long. The kegs have been returned to the contractor's shop.

March 5th. Cast iron base No. 24, rejected for developing cracks in handling; same has been replaced by a new base on March 10th.

March 8th. Two hundred tie rods rejected for being ⅝-inch diameter, versus ¾-inch; same have been replaced by ¾-inch rods on March 11th.

March 10th. 120 tie rods ¾-inch diameter, rejected for being too long; same will be accepted on condition that the iron erector shall provide each defective tie rod at each end with sufficient packing made of round iron washers.

March 14th. Columns JK 22 and JK 36, consisting of plates and channels riveted together, have been rejected on account of having rivets spaced 8 inches on centres instead of 6 inches. This case has been referred to the engineering department for consideration, and the columns are stored up on the job pending the decision.

March 20th. Two barrels of red paint rejected; on this date the painters ran short of paint. The painting foreman bought in the open market the above two barrels of paint. This paint consisted chiefly of kerosene mixed with a red coloring matter. The painter was ordered to remove at once the two barrels from the premises, before any of this paint was used.

Progress of the Work. In spite of adverse weather conditions before mentioned, the erection work was fairly satisfactory. During the month there have been erected all columns AB, CD, EF, for tiers 1 to 6 inclusive and all beams up to and including the sixth tier. All riveting has been completed, up to and including the fourth tier, and all iron work up to and taking in the third tier has received a field coat of paint. The painting was delayed for several days in compliance with my strict orders not to perform any painting on damp days. The derrick is now on the sixth tier, ready to set up the next row of columns. The brick work is up on the second tier, and floor arches on the third tier have been completely filled in.

Workmanship was generally satisfactory. Two riveting gangs persisting in doing careless work have been discharged

on the 3rd of March, and replaced by satisfactory men. Painting was done on dry, clear days only, and all iron work was carefully cleaned with a wire brush before the paint was applied.

Accidents during the month happened twice, but without serious consequences. On March 10th John Clarke, a riveter, failed to catch a red hot rivet while riveting on the fifth floor. The rivet fell in the street and badly injured a horse. On March 20th Jim Carrey, a fitter, dropped a tie rod from the sixth floor through the skylight of an adjoining building on the west side. Both accidents have been reported to the main office in the same days when they took place respectively.

In conclusion, I may state that the condition of the work in general is satisfactory. Considering the fact that the field force is well organized at present, and with the expectation that the weather during April will be better than during March, I earnestly hope for a much better progress during the coming month.

Respectfully submitted,

JOHN NEWTON,
Inspector Iron and Steel Construction.

CHAPTER XXIII.

QUESTIONS AND ANSWERS.

Following are the questions asked at previous examinations for Inspector of Iron and Steel Construction.

FIRST PAPER—QUESTIONS.

Technical.

1. How should specimens for testing be chosen and prepared to fairly show the quality of (a) wrought iron; (b) cast-iron?

2. What conditions or quality of material or manufacture are indicated by the following tensile test results: (a) Elastic limit 38,000 lbs. per sq. inch and ultimate strength 45,000 lbs. per sq. in.? (b) Ultimate strength 80,000 lbs. elongation in 8 inches 10%? (c) Ultimate strength 80,000 lbs. elongation in 8 inches 25%? (d) Ultimate strength 56,-000 lbs. elongation in 8 inches 35%?

3. What is the object of each of the following tests of wrought-steel: (a) cold bend; (b) hot bend; (c) quench and bend; (d) drift?

4. (a) Describe all the necessary details of surface examination of material. (b) State defects likely to be found in both steel and and cast iron.

5. What is (a) "piping"; (b) "burning"; (c) how do you inspect to discover them?

6. How are sections of the following forms checked: (a) Angles; (b) T's; (c) Wide sheared plates?

7. What are the essential points to be inspected about the following processes: (a) punching; (b) assembling?

8. (a) The same with riveting; (b) how are loose rivets made to seem tight under a hammer test; (c) how would you know deceit was practiced?

9. State all the details to be inspected of a girder of a finished plate-girder bridge span.

10. Same of a finished post for a pin-connected span.

11. How would you check the field connections of (a)

a skewed portal; (b) a lattice girder of which members are shipped separately?

12. What are the important points to be inspected about painting to secure thorough preservation from rust.

13. Describe details of inspection of all parts of a stringer floor-beam connection.

14. In first-class work what variations are allowable in the following: (a) Pin and pinhole connection; (b) riveted connection; (c) length of stringer; (d) length of floor beam; (e) length of eyebar; how should the last be measured.

15. How should a 16 in x 3/8 in. mill-plate 30 ft. long bowed in plans of its width (not buckled) be straightened; how if buckled?

Arithmetic.

1. The dimensions of the area of a test piece are 1.015 in. x .637 in. The testing machine shows elastic limit 22,080 lbs. and ultimate strength 40,250 lbs. The reduced area is .843 in. x .421 in., and the elongation in 8 in. is 2.84 in.: (a) What are the elastic limit and ultimate strength in lbs. per sq. inch; (b) what is the per cent. of reduction of area, and (c) what is the per cent. of elongation?

2. How much heavier is a 6 in. round bar than a 2 in. round bar, each 1 foot long? (Allow .26 1/3 lbs. to a cubic inch.)

3. The total weight of a steel viaduct is 563 tons 478 lbs. and 2/5 is girders, 1/3 is columns, 1/9 is bases, and the balance miscellaneous rods, etc. How much does each class of members weigh?

4. A plate 12 in. x 3/4 in. has a 7/8 in. rivet hole punched in it. What per cent. of section is removed?

SECOND PAPER—QUESTIONS.

Technical—Weight 5.

Date, June 30, 1911.
To be finished by one o'clock, June 30, 1911.

1. State briefly the difference between cast iron and structural steel as to the method of manufacture, use and general characteristics.

2. If punched holes through two pieces of steel fail to match by 1/4 inch. what should be done and what method of correction should not be followed.

3. What are the usual defects found in I beams indicating poor material or rolling?

4. For what reasons would you reject steel rods to be used to reinforce concrete?

5. What are the requirements as to separators used between (a) I beams in a grillage; (b) between double beams or channels?

6. If a column is not faced square what should be done?

7. Show by sketches, with dimensions, the standard connections for 4-inch, 12-inch and 24-inch I beams.

8. (a) How should holes for tie rods be spaced? (b) For what reasons would you reject tie rods?

9. What inspections should be made of cast iron columns, (a) before being set and (b) as tier above tier is set.

10. How is a rivet caulked and why should such a rivet be cut out and replaced?

1. What should be the inspection in order to get the best character of bolted work?

12. How would you determine if a floor of a building was being overloaded by materials of construction stored on it?

13. How should column bases be set?

14. (a) What is the difference in meaning between "plumb" and "perpendicular"? (b) What is the meaning of the term "coped" as applied to beams and channels? (c) What is "grout"? (d) "lintel"?

15. How should an inspector determine that a cast iron column is of uniform thickness?

Mathematics—Weight 1.

The following Mathematics and report are to be finished by 4 o'clock.

1. Add together 46.75 feet, 12 feet 4 inches, 39 inches, 7 feet 6 inches; divide the result by 17 and show the answer in feet and inches.

2. Add together 3 feet 6½ inches, 7⅜ inches, 18¾ inches, 11 feet 9⅞ inches; from the result subtract 9 feet 9¾ inches.

3. How many square yards of roof surface are there in a flat roof 36 feet 6 inches by 108 feet 4 inches.

Report—Weight 2.

Write a report of not less than two nor more than three pages covering the progress of construction of the steel frame of an important building during a month and including several matters to which an inspector might properly make objection and others requiring positive condemnation.

Following is one set of Answers to previous questions.

FIRST PAPER—ANSWERS.

Technical.

1. (a) Specimens for testing the qualities of wrought iron are cut from the full size bars or plates after rolling. Reproduce here Fig. 8, page 23, and its explanation. This piece is used for determining the tensile strength, elastic limit, ductility and ultimate strength.

1. (b) Specimens for testing the qualities of cast iron in bending are generally square or rectangular in cross section, say 1 in. x 1 in. or 3 in x 1 in. and either 14 in. or 26 in. long. These specimens are poured one before and one after the main casting is poured. For more close results several bars are tested and final averages are figured out. There should be at least one test bar for each ton of castings.

To test the cast iron in tension bars about 18 in. long are used. These are turned down in a lathe in order to remove surface scale and to make possible a more accurate measurement of the diameter of the bar. The turned part of the bar is divided into inches by means of a pointer, just as shown for steel specimens in the figure before mentioned.

2. (a) This specimen shows a high elastic limit and a low ultimate strength, usually found in material that has been sheared or punched and not annealed.

2. (b) This material is high carbon steel.

2. (c) This material is rolled nickel steel containing about three per cent. nickel. Mention properties of nickel steel as given on page 21. Shows high tensile strength and high ductility.

2. (d) This material is soft steel, also called rivet steel from its extensive use for rivets.

3. (a) To determine whether the specimen is cold-short, or high in phosphorus.

3. (b) To determine whether the specimen is red-short, or high in sulphur, arsenic, and other impurities.

3. (c) To determine whether the specimen will stand hardening.

3. (d) To determine how much a rivet hole could be enlarged by means of a drift pin or under similar conditions without fracturing the material.

For methods of performing these tests see page 23.

4. (a) In surface examinations the material should be examined as to color, grain, hardness and defects due to rolling or casting.

4. (b) Surface defects for steel are: Blow-holes, burning, cinder spots, cobbles, cracks, laps or laminations, pipes, pits, seams and snakes. Explain each term as on pages 21 and 22.

Surface defects for cast iron are: Blister, cold shuts, scales, swells and warpings.

5. (a) Piping. See page 21.

5. (b) Burning. See page 21.

5. (c) See page 21.

6. (a) To check the size of an angle measure the outside width of each leg and the thickness.

6. (b) To check the size of a T iron measure the width of the flange and the total height or depth of the T section; or else, whenever convenient weigh one of the shorter bars.

6. (c) To check the size of plates measure the width; then determine the exact thickness by using a measuring device known as calipers.

7. (a) The edges of the punch-dies must be sharp and unbroken. The dies must be of the required diameter. The difference between the upper and lower die should not exceed 1/16 in. All holes must be punched exactly where marked. See also page 28.

7. (b) Correct shapes, sizes and thickness must be assembled together. All holes must match exactly. The sizes and spacing of holes must agree with the plans.

8. (a) See page 41 under: Testing Rivets.

8. (b) See page 40.

8. (c) Examine the rivet head for caulking marks; inspect the plate for ridges that may be due to the use of the snap, when used so as to cut the plate and crowd the plate metal against the rivet head. See also pages 29 and 41.

9. To see that correct shapes and thickness are used. The web of the plate girder should not project above the flange angles.

The girder must be straight and free from twists or bends.

Stiffeners to be milled and to bear tight on top and bottom flange angles.

All rivets must be tight.

The number, diameter and spacing of field holes must agree with those shown on plans.

Web where spliced, must be made tightly close.

All the dimensions, including the spacing of the stiffenness, and the overall length and depth of the girder, must be correct.

10. To see that correct shapes and thickness are used.

All parts including the lattice bars, must be straight.

All abutting surfaces must be made tightly close.

All rivets must be tight.

The pin holes must be bored exactly at right angles to the length of the post.

The distance from centre to centre of pin holes, the diameter of the pin hole, and all other dimensions must be correct.

11. (a) For skewed connections try them on a wood template. This is a board with holes drilled in accordance with the drawings. Apply the template to one member, then to the other, while in the shop and see that holes in the two members match with the holes in the template.

11. (b) Assemble the girder in the shop using temporary bolts, and before shipping.

12. See page 52. Painting.

13. See that all holes are of the required diameter.

See that the required number of rivets has been provided in shop made connections.

See that the rivet heads are countersunk or chipped wherever so shown on the plans.

The holes must match exactly; all holes which do not match should be reamed out.

Rivets of sufficient length should be used.

Surfaces inaccessible after erection should be painted one field coat of good paint before erection.

14. (a) Pins less than 5 in. diam. should not be smaller than the pinhole by more than 1/50 of an inch; pins over 5 in. diam. should not be smaller than the pinhole by more than 1/32 of an inch.

14. (b) Holes in riveted connections should match exactly.

14. (c) A stringer should not be shorter than its figured length by more than 1/16 of an inch.

14. (d) Floor beams framing in between posts may be 1/16 to ⅛ of an inch shorter.

14. e) Eye bars 25 feet long or less may vary in length 1/16 inch. Also an additional 1/16 of an inch for every additional 25 feet in length.

To measure the exact length of an eye bar first find the distance between the outer edges of pinholes, then the distance between their inner edges. One half the sum of these two lengths is the correct length of the eye bar from centre to centre of pinholes.

15. The method used depends on the amount of the bend. Small bends are straightened by means of blows from a sledge hammer. This is especially the case with plates bent in their length or buckled.

Plates bowed in their width can be straightened out in the same manner, or else they may be passed through a straightening machine.

Arithmetic.

1. (a) Elastic Limit =34180; ultimate strength = 62300.

1. (b) Per cent. reduction of area = 45.1.

1. (c) Per cent. elongation = 35.5.

2. 6 in. round per foot weighs 88.328 lbs.
   2 in. round per foot weighs 8.682 lbs.
Difference 79.646 lbs.

3. Girders weigh =450591.2 lbs.
   Columns weigh = 375492.7 lbs.
   Bases weigh =125164.2 lbs.
   Miscellaneous = 175229.9 lbs.
   Total = 1126478.0 lbs.

A. Ans. 7.29 per cent.

SECOND PAPER—ANSWERS.

Technical.

1. Give definition, manufacture, properties, advantages and disadvantages of Cast Iron and Steel as given in Chapter III., pages 12 and 19.

2. Punched holes failing to match by ¼ inch should be reamed out. A drift pin should not be used for making holes to match. See also Fitting Connections on page 32.

3. For surface defects due to poor material and defective rolling see Answer to question 4, First paper. Bad material

is also shown by unsatisfactory appearance of the fracture. Give characteristics of bad fracture as given on page 20.

4. The rods may be too short, too long, of smaller cross-section, covered with rust or scales, badly twisted or bent, The material may be cold short or red short iron, or it may lack ductility and the required tensile resistance.

5. All separators must be not further apart than five feet on centres. Beams and channels 12 inches and over should have two bolts in each separator. See Sec. 117, Building Code, page 142.

Separators in grillage beams are made of gas pipes and bolts. Separators for beams or channels in walls are either made in the same manner or else they are cast iron separators with iron bolts. See also page 59.

6. Return the column to the shop and have it remilled. Then, if the column is too short, use a butt plate. In very bad cases reject the column.

7. See Fig. 33 on page 98.

8a. Tie rods should be spaced at distances not exceeding eight times the depth of the beams; also not exceeding eight feet. See Sec. 170, Building Code, page 143.

8b. Tie rods should be rejected when too short, too long, bent, of lighter cross section than specified on plans, or with insufficient bolt threads on either end.

Tie rods are usually ¾ in, rounds; when too long the excess length may be remedied by using washers as packing.

9a. Before setting examine the cast iron columns as to quality of metal (see pages 84-88) and as to diameter or width, thickness, length and correct lugs, seats and flanges.

9b. After setting see that all columns are made plumb, and that all bolts are put in. See that all columns bear evenly at flanges, and that none have been cracked during erection. See that columns of various tiers are not interchanged in setting.

10. See page 28 under Caulking.

11. All holes of parts to be connected by bolts should be drilled in the shop and made to match with the same template. For very good work use turned bolts. Turned bolts in reamed holes are often considered as being equivalent to rivets.

12. Overloading of a floor may be determined by sight examination or by computations. In the first case notice the amount of deflection of the floor. Also examine the under-

neath or the soffit for cracks or other indications of weakness.

A more definite way is to figure out the load approximately. Then compare the load carried by any one beam with the maximum safe capacity of that beam as given in tables IX.-XVI., in Part III.

13. See page 86. Setting cast iron bases.

14. (a) Plumb means vertical or in the direction of the plumb line.

Perpendicular. A line is perpendicular to another line when the two lines cross each other and form equal angles at their crossing.

14. (b) Coped. When a beam or a channel must frame into another beam or channel and the flanges of the two interfere by preventing the webs from coming close together, then the flange of the lighter beam is cut in the shop for a sufficient distance from the end to allow of proper framing. This operation is known as "coping" and the flange of the beam is "coped."

14. (c) Grout is a mixture of cement and sand, with sufficient water added to cause the mixture to flow easily. It is used in place of brick or concrete in open spaces in walls or in between grillage beams, where masons can not get in. Grout solidifies just like mortar by setting.

14. (d) Lintel is any horizontal beam resting on two vertical supports, i. e., Stone or iron lintels used in brick work over window openings.

15. See page 88 under Eccentricity.

Arithmetic.

Question 1. Ans. 4 feet 1 5/17 inches.

Question 2. Ans. 7 feet 8¾ inches.

Question 3. Ans. 3954 1/6 sq. ft. or 439 19/54 sq. yards.

Report. See page 185.

Erection and Inspection of Iron and Steel Constructions

PART III

CHAPTER XXIV.

Explanation of Tables.

GENERAL REMARKS.

The following tables have been added to this volume in order to form a ready reference for the inspectors and builders while in the field. Some of these tables are entirely indispensable for the inspector in checking up the sizes of various steel beams or columns. Other tables may be used advantageously in investigating floor framings in cases of overloading, and under many other conditions.

The material in some of these tables has been compiled by the author from various tables in common use at the present time. Many good tables are found in the mill books issued by the various rolling mills, like the Carnegie Steel Company, the Cambria Steel Company, the Bethlehem Steel Company, and so on. The author believes, however, that the tables contained in this volume will be found sufficient for all field purposes.

Of course, the various tables in existence have been carefully compared, and the doubtful figures recomputed. All the tables have been rearranged, most of them have been extended in order to make them more useful for field uses, and several of the tables are entirely original.

In considering them in order, wew shall point out a few of the many ways in which these tables can be used in inspecting iron and steel constructions.

Table I. Wire and Sheet Metal Gauges. A "wire gauge" is a method of indicating the diameter of wires or the thickness of sheets of metal by referring to the numbers of a table arranged on a certain fixed and arbitrary basis.

There are at present at least ten different wire gauges, resulting in great confusion. The most important gauges in use in this country are as follows:

The United States Standard Steel Plate Gauge, which is the only legal gauge in this country. It is given in the fourth column of the table, and is mostly used by the manufacturers of sheet iron, steel and tin-plate.

The Brown & Sharpe guage is given in the second column of the table, and is commonly used for copper wires, sheet copper, brass, and sheet iron or steel, i. e., by special order of the Bureau of Buildings all outside

metal smoke flues in Manhattan must be made of galvanized sheet steel, not less than No. 8 B. & S. gauge in thickness. According to the table, this would mean a thickness equal to .128490, or a little over one-eighth of an inch. Similarly, the metal used in making iron treads and risers for interior stairways is often specified to be of No. 12 gauge. With poor supervision this would be replaced by sheet metal No. 16 gauge.

To determine gauges in the field, either one of these methods may be used:

(a) By means of a gauge ring. This consists of a circular metal plate with indentations all around the outer edge. The indentations are made to correspond with the diameters of the various wire gauge numbers.

(b) By weighing any convenient portion of the sheet metal, say, several square feet. The weight per square foot for steel plates corresponding to the various gauge numbers will be found in the third column of the table.

(c) The gauge numbers are generally painted on the original plates by the manufacturers.

Table II. Shearing and Bearing Value of Rivets.

The values given in this table are safe values, in accordance with the New York Building Code. Single shear is figured at 10,000 pounds per square inch. As the ultimate shearing strength for steel is about 50,000 pounds per square inch, it follows that good rivets will stand in shear before failing about five times as much as given in the table.

The shearing resistance of a rivet in double shear is just twice the value for single shear given in the fourth column.

Table III. Length of Rivets for Various Grips.

In this table the length of the rivet is taken to mean the distance from under the head of the cold rivet to the free end of the shank. This is the common meaning of the length of a rivet or bolt and is illustrated on top of the table.

Table IV. Properties of American Standard and Special I-Beams.

This table gives the depth, weight and area of American sections. The thickness of the web is also given. Column five gives the width across the top of the beam or the width of the flange.

Checking Sizes. The figures in column five are used in determining the weight of a beam. For instance, a 24 in. I

weighs 80 pounds per foot when it measures 7 in. across the flange; or it weighs 100 pounds per foot when the width across the flange is 7.25 in. As an additional check compare also the thicknesses of the webs, as given in column four.

Moment of Inertion. Consider an I-beam section as shown at the bottom of Table V. Draw this section for any one I-beam in full size. Then divide the section into, say, twenty equal parts. Then draw line AA. Now multiply the area of each part by the square of the distance between the centre of such part and the line AA. You will get twenty products. Their sum is an approximate value of the Moment of Inertia of that particular section and will not be far from the values given for each section in column six. The line AA is called the Neutral Axis at right angles to the web. The line BB is another neutral axis, but parallel to the web.

The Moment of Inertia of a section is the algebraic sum of all the products obtained by multiplying each small particle of the area of the section by the square of its distance from the neutral axis.

The moments of inertia for various sections with reference to axes AA and BB are given in columns 6 and 7 under I and I′ respectively.

Radius of Gyration. Divide the moment of inertia by the area in square inches. The square root of the number thus found is called the radius of gyration.

The radius of gyration for various sections are given in columns 8 and 9.

Section Modulus. Divide the moment of inertia by one-half the depth of the section in inches. The result is the section modulus.

Section moduli for various beams are given in column 10. This is the more used section modulus, or the one about the axis AA.

Table V. Properties of American Standard and Special Channels. The arrangement of this table is similar to that of Table IV., and no further explanation is deemed necessary.

Table VI. Properties of Standard and Special Angles.

This table gives the size, weight and area as well as other properties of angles with equal legs. Column 4 gives the distance from the centre of gravity of the angle to the back of the flange. The moments of inertia, section moduli and radii of gyration about two axes are given. These axes are shown in the diagrams as AA and BB.

For a list of common angles with unequal legs see Table XIV.

Table VII. Properties of Bethlehem I-Beams and Bethlehem Girder Beams.

These sections are rolled by the Grey Mills at Bethlehem, Pa., and represent some of the latest improvements in rolled sections. Bethlehem sections have been in use in this country since about 1908, and their use in buildings is constantly increasing. The beams and girders have wide and heavy flanges as shown approximately in the figures at the bottom of Table VII. All flanges of both beam and girder sections have a uniform bevel of 9 per cent. Bethlehem shapes may vary in weight up to 2½ per cent. from the weight given in this table.

Bethlehem beams are more economical than standard beams, on account of a better distribution of the metal in the section. In column II is given the equivalent standard beam or beams which have about the same carrying capacity as the corresponding Bethlehem sections.

Table VIII. Properties of Bethlehem H Columns.

These columns have an H shaped section with a uniform flange slope of 2 per cent. H columns may vary in weight up to 2½ per cent. from the nominal section.

H columns are often used in buildings of moderate heights. They give a stronger job than built-up sections, require little shop work, and hence they save in costs. For very tall buildings, however, the columns required for the lower stories become too heavy to be punched in the flanges, and drilling must be resorted to. This is one of the reasons why Bethlehem H sections are not used in very tall buildings.

Tables IX. to XIV. Safe Loads Uniformly Distributed.

These tables give the safe loads uniformly distributed on standard and special I-beams, channels, and angles for usual spans. The span means the actual unsupported length, that is, the clear span. The loads are given in tons of 2,000 pounds.

Concentrated Loads.

When the load is all concentrated at the middle of the span, the safe carrying capacity of the beam is only one-half the value given in the tables for uniform loads.

Design of Beams. The safe loads in these tables have been figured from the formula:

Uniform safe loads in pounds $= 8\ KI \div ld$

where $K =$ maximum allowable fibre stress per sq. inch, and which was taken at 16,000 pounds per sq. in. for steel.

$I =$ Moment of Inertia as defined for Table IV.

$l =$ span in inches.

and $d =$ one-half the depth of the beam in inches.

Table XV. Safe Loads on Channels Set Flatwise.
Channels set flatwise are often used as lintels. The strength of such channels is comparatively small even with the heavier channel sections. The values in these tables have been figured in a similar way as for Table IX.

Table XVI. Safe Loads for Cast-iron Columns.
This table has been figured by the author from the formula:
Safe load per sq. inch of section for cast-iron columns:

$$= 11300 - 30 \frac{l}{r}$$

where l = unsupported length of column in inches and r = least radius of gyration (See notes on table IV.).
For steel columns the formula becomes:
Safe load per sq. inch of section for steel columns:

$$= 15200 - 58 \frac{l}{r}$$

These formulae are in accordance with the requirements of the New York Building Code.

For steel columns $\frac{l}{r}$ should not exceed 120.

Table XVII. Standard Shapes Used as Struts.
This table will be found useful in the field in checking the unsupported lengths of struts in exterior stairways and under similar circumstances.
The lengths are just within the limit of

$$l \div r = 120.$$

The loads are figured from formula given in Table VI.

Table XVIII. Capacity of Cylindrical Tanks.
By formula:
Capacity in cubic feet = 3.14 x r x r x h
where r = radius of the bottom in feet
and h = height of the tank in feet.
From the table:
Get the capacity in gallons for one foot of height and multiply by the height in feet.

Tables XIX.-XX. Conversion Tables.
These tables are self-explanatory.

TABLE 1. WIRE AND SHEET METAL GAUGES.

Number of Gauge.	American or Brown & Sharpe Wire Gauge	Weight per sq. ft. for Steel Plates, B. & S. Gauge	U. S. Standard Steel Plate Gauge	Approx. Thickness in inches for Plates. U. S. Standard	Number of Gauge	American or Brown & Sharpe Wire Gauge	Weight per sq. ft. for Steel Plates, B. & S. Gauge	U. S. Standard Steel Plate Gauge	Approx. Thickness in inches for Plates, U. S. Standard	Number of Gauge.	American or Brown & Sharpe Wire Gauge	Weight per sq. ft. for Steel Plates, B. & S. Gauge	U. S. Standard Steel Plate Gauge	Approx. Thickness in inches for Plates. U. S. Standard
7–0			.5	1/2	10	.101897	4.14	.140625	9/64	26	.015941	.648	.01875	3/160
6–0			.46875	15/32	11	.090742	3.69	.125	1/8	27	.014195	.577	.0171875	11/640
5–0			.4375	7/16	12	.080808	3.29	.109375	7/64	28	.012641	.514	.015625	1/64
4–0	.460000	18.70	.40625	13/32	13	.071962	2.93	.09375	3/32	29	.011257	.458	.0140625	9/640
3–0	.409642	16.66	.375	3/8	14	.064084	2.61	.078125	5/64	30	.010025	.408	.0125	1/80
2–0	.364796	14.83	.34375	11/32	15	.057068	2.32	.0703125	9/128	31	.008928	.363	.0109375	7/640
0	.324861	13.21	.3125	5/16	16	.050821	2.07	.0625	1/16	32	.007950	.323	.01015625	13/1280
1	.289297	11.76	.28125	9/32	17	.045257	1.84	.05625	9/160	33	.007080	.288	.009375	3/320
2	.257627	10.48	.265625	17/64	18	.040303	1.64	.05	1/20	34	.006305	.256	.00859375	11/1280
3	.229423	9.33	.25	1/4	19	.035890	1.46	.04375	7/160	35	.005615	.228	.0078125	5/640
4	.204307	8.31	.234375	15/64	20	.031961	1.30	.0375	3/80	36	.005000	.203	.00703125	9/1280
5	.181940	7.40	.21875	7/32	21	.028462	1.16	.034375	11/320	37	.004453	.181	.006640625	17/2560
6	.162023	6.59	.203125	13/64	22	.025346	1.03	.03125	1/32	38	.003965	.161	.00625	1/160
7	.144285	5.87	.1875	3/16	23	.022572	.918	.028125	9/320	39	.003531	.143		
8	.128490	5.22	.171875	11/64	24	.020101	.817	.025	1/40	40.	.003144	.127		
9	.114423	4.65	.15625	5/32	25	.017900	.728	.021875	7/320					

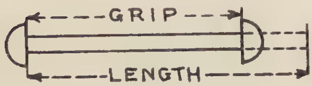
All thicknesses are given in inches. All weights are given in pounds.
Weight per cubic foot for steel=487.75; iron=481.25; brass=513.6; copper=543.6.
Weight per cubic inch for steel=.2823; iron=.2787; brass=.2972; copper=.3146.

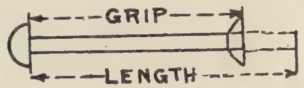
TABLE II. SHEARING AND BEARING VALUE OF RIVETS.

Diameter of rivet in inches		Area of rivet sq. in.	Single Shear at 10000 lbs. per sq. in.	Bearing value for different thicknesses of plate at 20,000 lbs. per sq. in. — Thickness of plate in inches.												
Fraction	Decimal			1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1″
3/8	.375	.1104	.1104	1875	2344	2813										
7/16	.4375	.1503	.1503	2187	2734	3281	3828									
1/2	.5	.1963	.1963	2500	3125	3750	4375									
9/16	.5625	.2485	.2485	2812	3515	4219	4922	5625	6328							
5/8	.625	.3068	.3068	3125	3906	4688	5469	6250	7031	7813						
11/16	.6875	.3712	.3712	3437	4297	5156	6016	6875	7734	8594	9454					
3/4	.75	.4418	.4418	3750	4688	5625	6563	7500	8438	9375	10313	11250				
13/16	.8125	.5185	.5185	4062	5078	6094	7109	8125	9141	10156	11172	12187	13002			
7/8	.875	.6013	.6013	4375	5469	6563	7656	8750	9844	10938	12031	13125	14219	15313		
15/16	.9375	.6903	.6903	4687	5859	7031	8203	9375	10547	11719	12890	14062	15234	16406	17578	
1	1.000	.7854	.7854	5000	6250	7500	8750	10000	11250	12500	13750	15000	16250	17500	18750	20000
1 1/16	1.0625	.8866	.8866	5312	6640	7968	9296	10625	11953	13281	14609	15937	17265	18593	19922	21250
1 1/8	1.125	.9940	.9940	5624	7030	8436	9842	11250	12656	14062	15468	16874	18280	19686	21094	22500
1 3/16	1.1875	1.1075	1.1075	5936	7420	8904	10388	11875	13359	14843	16327	17811	19295	20779	22266	23750
1 1/4	1.25	1.2272	1.2272	6249	7810	9372	10934	12500	14062	15624	17186	18748	20310	21872	23438	25000

TABLE III. LENGTH OF RIVETS FOR VARIOUS GRIPS.

These lengths include the amount of shank necessary to form one head.





1	2	3	4	5	6	7
Grip in inches	Diameter of rivet in inches					
	⅜	½	⅝	¾	⅞	1
½	1¼	1½	1¾	1⅞	2	2⅛
⅝	1⅜	1⅝	1⅞	2	2⅛	2¼
¾	1½	1¾	2	2⅛	2¼	2⅜
⅞	1⅝	1⅞	2⅛	2¼	2⅜	2½
1	1¾	2	2¼	2⅜	2½	2⅝
1⅛	1⅞	2⅛	2⅜	2½	2⅝	2¾
1¼	2	2¼	2½	2⅝	2¾	2⅞
1⅜	2⅛	2⅜	2⅝	2¾	2⅞	3
1½	2¼	2⅝	2⅞	3	3⅛	3¼
1⅝	2⅜	2¾	2	3⅛	3¼	3⅜
1¾	2½	2⅞	3⅛	3¼	3⅜	3½
1⅞	2⅝	3	3¼	3⅜	3½	3⅝
2	2¾	3⅛	3⅜	3½	3⅝	3¾
2⅛	2⅞	3¼	3½	3⅝	3¾	3⅞
2¼	3	3⅜	3⅝	3¾	3⅞	4
2⅜	3⅛	3½	3¾	3⅞	4	4⅛
2½	3¼	3⅝	3⅞	4	4⅛	4¼
2⅝	3½	3¾	4	4⅛	4¼	4⅜
2¾	3⅝	3⅞	4⅛	4¼	4⅜	4½
2⅞	3¾	4	4¼	4⅜	4½	4⅝
3	3⅞	4¼	4½	4⅝	4¾	4⅞
3⅛	4	4⅜	4⅝	4¾	4⅞	5
3¼	4⅛	4½	4¾	4⅞	5	5⅛
3⅜	4¼	4⅝	4⅞	5	5⅛	5¼
3½	4⅜	4¾	5	5⅛	5¼	5⅜
3⅝	4½	4⅞	5⅛	5¼	5⅜	5½
3¾	4⅝	5	5¼	5⅜	5½	5⅝
3⅞	4¾	5⅛	5⅜	5½	5⅝	5¾
4	4⅞	5¼	5½	5⅝	5¾	5⅞
4⅛	5	5⅜	5⅝	5¾	5⅞	6
4¼	5⅛	5½	5¾	5⅞	6	6⅛
4⅜	5¼	5⅝	5⅞	6	6⅛	6¼
4½	5⅜	5¾	6	6¼	6⅜	6½
4⅝	5½	5⅞	6¼	6⅜	6½	6⅝
4¾	5⅝	6	6⅜	6½	6⅝	6¾
4⅞	5¾	6⅛	6½	6⅝	6¾	6⅞
5	5⅞	6¼	6⅝	6¾	6⅞	7
5⅛	6	6⅜	6¾	6⅞	7	7⅛
5¼	6⅛	6½	6⅞	7	7⅛	7¼
5⅜	6¼	6⅝	7	7⅛	7¼	7⅜
5½	6⅜	6¾	7⅛	7¼	7⅜	7½
5⅝	6½	6⅞	7¼	7⅜	7½	7⅝
5¾	6¾	7	7⅜	7⅝	7⅝	7¾
5⅞	6⅞	7⅛	7½	7¾	7¾	7⅞
6	7	7¼	7⅝	7⅞	7⅞	8

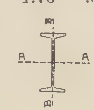
1	2	3	4	5	6	7
Grip in inches	Diameter of rivet in inches					
	⅜	½	⅝	¾	⅞	1
½	1	1⅛	1¼	1¼	1⅜	1⅜
⅝	1⅛	1¼	1⅜	1⅜	1½	1½
¾	1¼	1⅜	1½	1½	1⅝	1⅝
⅞	1⅜	1½	1⅝	1⅝	1¾	1¾
1	1½	1⅝	1¾	1¾	1⅞	1⅞
1⅛	1⅝	1¾	1⅞	1⅞	2	2
1¼	1¾	1⅞	2	2	2⅛	2⅛
1⅜	1⅞	2	2⅛	2⅛	2¼	2¼
1½	2	2⅛	2¼	2⅜	2⅜	2½
1⅝	2⅛	2¼	2⅜	2½	2½	2⅝
1¾	2¼	2⅜	2½	2⅝	2⅝	2¾
1⅞	2⅜	2½	2⅝	2¾	2¾	2⅞
2	2½	2⅝	2¾	2⅞	2⅞	3
2⅛	2⅝	2¾	2⅞	3	3	3⅛
2¼	2¾	2⅞	3	3⅛	3⅛	3¼
2⅜	2⅞	3	3⅛	3¼	3¼	3⅜
2½	3	3⅛	3¼	3⅜	3⅜	3½
2⅝	3¼	3¼	3⅜	3½	3½	3⅝
2¾	3⅜	3⅜	3½	3⅝	3⅝	3¾
2⅞	3½	3½	3⅝	3¾	3¾	3⅞
3	3⅝	3¾	3⅞	3⅞	4	4⅛
3⅛	3¾	3⅞	4	4	4⅛	4¼
3¼	3⅞	4	4⅛	4⅛	4¼	4⅜
3⅜	4	4⅛	4¼	4¼	4⅜	4½
3½	4⅛	4¼	4⅜	4⅜	4½	4⅝
3⅝	4¼	4⅜	4½	4½	4⅝	4¾
3¾	4⅜	4½	4⅝	4⅝	4¾	4⅞
3⅞	4½	4⅝	4¾	4¾	4⅞	5
4	4⅝	4¾	4⅞	4⅞	5	5⅛
4⅛	4¾	4⅞	5	5	5⅛	5¼
4¼	4⅞	5	5⅛	5⅛	5¼	5⅜
4⅜	5	5⅛	5¼	5¼	5⅜	5½
4½	5⅛	5¼	5⅜	5½	5½	5⅝
4⅝	5¼	5½	5⅝	5⅝	5⅝	5¾
4¾	5⅜	5⅝	5¾	5¾	5¾	5⅞
4⅞	5½	5¾	5⅞	5⅞	5⅞	6
5	5⅝	5⅞	6	6⅛	6⅛	6⅛
5⅛	5¾	6	6⅛	6¼	6¼	6¼
5¼	5⅞	6⅛	6¼	6⅜	6⅜	6⅜
5⅜	6	6¼	6⅜	6½	6½	6½
5½	6⅛	6⅜	6½	6⅝	6⅝	6⅝
5⅝	6¼	6½	6⅝	6¾	6¾	6¾
5¾	6½	6⅝	6¾	6⅞	6⅞	6⅞
5⅞	6⅝	6¾	6⅞	7	7	7
6	6¾	6⅞	7	7⅛	7⅛	7⅛

TABLE IV. PROPERTIES OF AMERICAN STANDARD AND SPECIAL I-BEAMS.

1	2	3	4	5	6	7	8	9	10
Depth of beam ins.	W't per foot lbs.	Area of section sq. in.	Thickness of web ins.	Width of flange ins.	Moment of inertia: I Axis A-A	Moment of inertia: I′ Axis B-B	Radius of gyration: r Axis A-A	Radius of gyration: r′ Axis B-B	Section Modulus S Axis A-A
24	80.	23.32	.50	7.00	2087.9	42.86	9.46	1.36	174.0
	85.	25.00	.57	7.07	2168.6	44.35	9.31	1.33	180.7
	90.	26.47	.63	7.13	2239.1	45.70	9.20	1.31	186.6
	95.	27.94	.69	7.19	2309.6	47.10	9.09	1.30	192.5
	100.	29.41	.75	7.25	2380.3	48.56	9.00	1.28	198.4
20	65.	19.08	.50	6.25	1169.6	27.86	7.83	1.21	117.0
	70.	20.59	.58	6.32	1219.9	29.04	7.70	1.19	122.0
	75.	22.06	.65	6.40	1268.9	30.25	7.58	1.17	126.9
	80.	23.73	.60	7.00	1466.5	45.81	7.86	1.39	146.7
	85.	25.00	.66	7.06	1508.7	47.25	7.77	1.37	150.9
	90.	26.47	.74	7.14	1557.8	48.98	7.67	1.36	155.8
	95.	27.94	.81	7.21	1606.8	50.78	7.58	1.35	160.7
	100.	29.41	.88	7.28	1655.8	52.65	7.50	1.34	165.6
18	55.	15.93	.46	6.00	795.6	21.19	7.07	1.15	88.4
	60.	17.65	.56	6.09	841.8	22.38	6.91	1.13	93.5
	65.	19.12	.64	6.18	881.5	23.47	6.79	1.11	97.9
	70.	20.59	.72	6.26	921.3	24.62	6.69	1.09	102.4
15	42.	12.48	.41	5.50	441.7	14.62	5.95	1.08	58.9
	45.	13.24	.46	5.55	455.8	15.09	5.87	1.07	60.8
	50.	14.71	.56	5.65	483.4	16.04	5.73	1.04	64.5
	55.	16.18	.66	5.75	511.0	17.06	5.62	1.02	68.1
	60.	17.67	.59	6.00	609.0	25.96	5.87	1.21	81.2
	65.	19.12	.69	6.10	636.0	27.42	5.77	1.20	84.8
	70.	20.59	.78	6.19	663.6	29.00	5.68	1.19	88.5
	75.	22.06	.88	6.29	691.2	30.68	5.60	1.18	92.2
	80.	23.81	.81	6.40	795.5	41.76	5.78	1.32	106.1
	85.	25.00	.89	6.48	817.8	43.57	5.72	1.32	109.0
	90.	26.47	.99	6.58	845.4	45.91	5.65	1.32	112.7
	95.	27.94	1.08	6.67	872.9	48.37	5.59	1.32	116.4
	100.	29.41	1.18	6.77	900.5	50.98	5.53	1.31	120.1
12	31.5	9.26	.35	5.00	215.8	9.50	4.83	1.01	36.0
	35.0	10.29	.44	5.09	228.3	10.07	4.71	0.99	38.0
	40.0	11.84	.46	5.25	268.9	13.81	4.77	1.08	44.8
	45.0	13.24	.58	5.40	28.75	14.89	4.65	1.06	47.6
12	50.0	14.71	.70	5.49	303.3	16.12	4.54	1.05	50.6
	55.0	16.18	.82	5.61	321.0	17.46	4.45	1.04	53.5
10	25.	7.37	.31	4.66	122.1	6.89	4.07	.97	24.4
	30.	8.82	.45	4.80	134.2	7.65	3.90	.93	26.8
	35.	10.29	.60	4.95	146.4	8.52	3.77	.91	29.3
	40.	11.76	.75	5.10	158.7	9.50	3.67	.90	31.7
9	21.	6.31	.29	4.33	84.9	5.16	3.67	.98	18.9
	25.	7.35	.41	4.45	91.9	5.65	3.54	.88	20.4
	30.	8.82	.57	4.61	101.9	6.42	3.40	.85	22.6
	35.	10.29	.73	4.77	111.8	7.31	3.29	.84	24.8
8	18.0	5.33	.27	4.00	56.9	3.78	3.27	.84	14.2
	20.5	6.03	.36	4.09	60.6	4.07	3.17	.82	15.1
	23.0	6.76	.45	4.18	64.5	4.39	3.09	.81	16.1
	25.5	7.50	.54	4.27	68.4	4.75	3.02	.80	17.1
7	15.0	4.42	.25	3.66	36.2	2.67	2.86	.78	10.4
	17.5	5.15	.35	3.76	39.2	2.94	2.76	.76	11.2
	20.0	5.88	.46	3.87	42.2	3.24	2.68	.74	12.1
6	12.25	3.61	.23	3.33	21.8	1.85	2.46	.72	7.3
	14.75	4.34	.35	3.45	24.0	2.09	2.35	.69	8.0
	17.25	5.07	.47	3.57	26.2	2.36	2.27	.68	8.7
5	9.75	2.87	.21	3.00	12.1	1.23	2.05	.65	4.8
	12.25	3.60	.36	3.15	13.6	1.45	1.94	.63	5.4
	14.75	4.34	.50	3.29	15.2	1.70	1.87	.63	6.1
4	7.50	2.21	.19	2.66	6.0	.77	1.64	.59	3.0
	8.50	2.50	.26	2.73	6.4	.85	1.59	.58	3.2
	9.50	2.73	.34	2.81	6.7	.93	1.55	.58	3.4
	10.50	3.09	.41	2.88	7.1	1.01	1.52	.57	3.6
3	5.50	1.63	.17	2.33	2.5	.46	1.23	.53	1.7
	6.50	1.91	.26	2.42	2.7	.53	1.19	.52	1.8
	7.50	2.21	.36	2.52	2.9	.60	1.15	.52	1.9

TABLE V. PROPERTIES OF AMERICAN STANDARD AND SPECIAL CHANNELS.

1	2	3	4	5	6	7	8	9	10
					Moment of inertia		Radius of gyration		
Depth of beam ins.	Wt. per foot lbs.	Area of section sq. in.	Thickness of web ins.	Width of flange ins.	I Axis A-A	I′ Axis B-B	r Axis A-A	r′ Axis B-B	Section modulus S
15	33	9.90	.40	3.40	312.6	8.23	5.62	.91	41.7
	35	10.29	.43	3.43	320.0	8.48	5.58	.91	42.7
	40	11.76	.52	3.52	347.5	9.39	5.43	.89	46.3
	45	13.24	.62	3.62	375.1	10.29	5.32	.88	50.0
	50	14.71	.72	3.72	402.7	11.22	5.23	.87	53.7
	55	16.18	.82	3.82	430.2	12.19	5.16	.87	57.4
12	20½	6.03	.28	2.94	128.1	3.91	4.61	.81	21.4
	25	7.35	.39	3.05	144.0	4.53	4.43	.78	24.0
	30	8.82	.51	3.17	161.7	5.21	4.28	.77	26.9
	35	10.29	.64	3.30	179.3	5.90	4.17	.76	29.9
	40	11.76	.76	3.42	197.0	6.63	4.09	.75	32.8
10	15	4.46	.24	2.60	66.9	2.30	3.87	.72	13.4
	20	5.88	.38	2.74	78.7	2.85	3.66	.70	15.7
	25	7.35	.53	2.89	91.0	3.40	3.52	.68	18.2
	30	8.82	.68	3.04	103.2	3.99	3.42	.67	20.6
	35	10.29	.82	3.18	115.5	4.66	3.35	.67	23.1
9	13¼	3.89	.23	2.43	47.3	1.77	3.49	.67	10.5
	15	4.41	.29	2.49	50.9	1.95	3.40	.66	11.3
	20	5.88	.45	2.65	60.8	2.45	3.21	.65	13.5
	25	7.35	.61	2.81	70.7	2.98	3.10	.64	15.7
8	11¼	3.35	.22	2.26	32.3	1.33	3.11	.63	8.1
	13¾	4.04	.31	2.35	36.0	1.55	2.98	.62	9.0
	16¼	4.78	.40	2.44	39.9	1.78	2.89	.61	10.0
	18¾	5.51	.49	2.53	43.8	2.01	2.82	.60	11.0
	21¼	6.25	.58	2.62	47.8	2.25	2.77	.60	11.9
7	9¾	2.85	.21	2.09	21.1	.98	2.72	.59	6.0
	12¼	3.60	.32	2.20	24.2	1.19	2.59	.57	6.9
	14¾	4.34	.42	2.30	27.2	1.40	2.50	.57	7.8
	17¼	5.07	.53	2.41	30.2	1.62	2.44	.56	8.6
	19¾	5.81	.63	2.51	33.2	1.85	2.39	.56	9.5
6	8	2.38	.20	1.92	13.0	.70	2.34	.54	4.3
	10½	3.09	.32	2.04	15.1	.88	2.21	.53	5.0
	13	3.82	.44	2.16	17.3	1.07	2.13	.53	5.8
	15½	4.56	.56	2.28	19.5	1.28	2.07	.53	6.5
5	6½	1.95	.19	1.75	7.4	.48	1.95	.50	3.0
	9	2.65	.33	1.89	8.9	.64	1.83	.49	3.5
	11½	3.38	.48	2.04	10.4	.82	1.75	.49	4.2
4	5¼	1.55	.18	1.58	3.8	.32	1.56	.45	1.9
	6¼	1.84	.25	1.65	4.2	.38	1.51	.45	2.1
	7¼	2.13	.32	1.72	4.6	.44	1.46	.45	2.3
3	4	1.19	.17	1.41	1.6	.20	1.17	.41	1.1
	5	1.47	.26	1.50	1.8	.25	1.12	.41	1.2
	6	1.76	.36	1.60	2.1	.31	1.08	.42	1.4



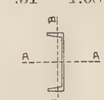


TABLE VI. PROPERTIES OF STANDARD AND SPECIAL ANGLES WITH EQUAL LEGS.

1	2	3	4	5	6	7	8	9	10
				Neutral Axis through Centre of Gravity and					
				parallel to flange			at 45° to flange		
Size in inches	W't per foot lbs.	Area in sq. ins.	Dist. C.G. to back of flange	I	S	r	I′	S′	r′
8x8x1⅛	56.9	16.73	2.41	97.97	17.53	2.42	40.33	11.83	1.55
8x8x1 1/16	54.0	15.87	2.39	93.53	16.67	2.43	38.38	11.36	1.56
8x8x1	51.0	15.00	2.37	88.98	15.80	2.44	36.40	10.88	1.56
8x8x 15/16	48.1	14.12	2.34	84.33	14.91	2.44	34.40	10.38	1.56
8x8x ⅞	45.0	13.23	2.32	79.58	14.01	2.45	32.38	9.86	1.57
8x8x 13/16	42.0	12.34	2.30	74.71	13.11	2.46	30.33	9.33	1.57
8x8x ¾	38.9	11.44	2.28	69.74	12.18	2.47	28.24	8.77	1.57
8x8x 11/16	35.8	10.53	2.25	64.64	11.25	2.48	26.13	8.20	1.58
8x8x ⅝	32.7	9.61	2.23	59.42	10.30	2.49	23.97	7.60	1.58
8x8x 9/16	29.6	8.68	2.21	54.09	9.34	2.50	21.79	6.98	1.58
8x8x ½	26.4	7.75	2.19	48.64	8.37	2.51	19.56	6.33	1.58
6x6x1	37.4	11.00	1.86	35.46	8.57	1.80	14.78	5.61	1.16
6x6x 15/16	35.3	10.37	1.84	33.72	8.11	1.80	13.98	5.37	1.16
6x6x ⅞	33.1	9.74	1.82	31.92	7.64	1.81	13.17	5.12	1.17
6x6x 13/16	31.0	9.09	1.80	30.06	7.15	1.82	12.35	4.86	1.17
6x6x ¾	28.7	8.44	1.78	28.15	6.66	1.83	11.52	4.59	1.17
6x6x 11/16	26.5	7.78	1.75	26.19	6.17	1.83	10.67	4.31	1.17
6x6x ⅝	24.2	7.11	1.73	24.16	5.66	1.84	9.81	4.01	1.18
6x6x 9/16	21.9	6.43	1.71	22.07	5.14	1.85	8.94	3.70	1.18
6x6x ½	19.6	5.75	1.68	19.91	4.61	1.86	8.04	3.37	1.18
6x6x 7/16	17.2	5.06	1.66	17.68	4.07	1.87	7.13	3.04	1.19
6x6x ⅜	14.9	4.36	1.64	15.39	3.53	1.88	6.19	2.67	1.19
5x5x1	30.6	9.00	1.61	19.64	5.80	1.48	8.29	3.65	0.96
5x5x 15/16	28.9	8.50	1.59	18.71	5.49	1.48	7.83	3.48	0.96
5x5x ⅞	27.2	7.99	1.57	17.75	5.17	1.49	7.37	3.32	0.96
5x5x 13/16	25.4	7.46	1.55	16.77	4.85	1.50	7.02	3.20	0.97
5x5x ¾	23.6	6.94	1.52	15.74	4.53	1.51	6.54	3.02	0.97
5x5x 11/16	21.8	6.42	1.50	14.68	4.20	1.51	6.03	2.84	0.97
5x5x ⅝	20.0	5.86	1.48	13.58	3.86	1.52	5.55	2.66	0.97
5x5x 9/16	18.1	5.31	1.46	12.44	3.51	1.53	5.06	2.46	0.98
5x5x ½	16.2	4.75	1.43	11.25	3.15	1.54	4.56	2.25	0.98
5x5x 7/16	14.3	4.18	1.41	10.02	2.79	1.55	4.05	2.03	0.98
5x5x ⅜	12.3	3.61	1.39	8.74	2.42	1.56	3.53	1.79	0.99
4 x4 x⅞	21.2	6.24	1.31	8.59	3.20	1.17	3.69	1.99	0.77
4 x4 x 13/16	19.9	5.84	1.29	8.14	3.01	1.18	3.46	1.89	0.77
4 x4 x¾	18.5	5.44	1.27	7.67	2.81	1.19	3.23	1.80	0.77
4 x4 x 11/16	17.1	5.03	1.25	7.17	2.61	1.19	3.00	1.70	0.77
4 x4 x⅝	15.7	4.62	1.23	6.66	2.40	1.20	2.76	1.59	0.77
4 x4 x 9/16	14.3	4.18	1.21	6.12	2.19	1.21	2.52	1.48	0.78
4 x4 x½	12.8	3.75	1.18	5.56	1.97	1.22	2.28	1.36	0.78
4 x4 x 7/16	11.3	3.31	1.16	4.97	1.75	1.23	2.02	1.23	0.78
4 x4 x⅜	9.8	2.86	1.14	4.36	1.52	1.23	1.77	1.10	0.79
4 x4 x 5/16	8.2	2.40	1.12	3.71	1.29	1.24	1.50	0.95	0.79
3½x3½x⅞	18.3	5.36	1.19	5.53	2.39	1.02	2.43	1.45	0.67
3½x3½x 13/16	17.1	5.03	1.17	5.25	2.25	1.02	2.28	1.38	0.67
3½x3½x¾	16.0	4.69	1.15	4.96	2.11	1.03	2.13	1.31	0.67
3½x3½x 11/16	14.8	4.34	1.12	4.65	1.96	1.04	1.97	1.24	0.67
3½x3½x⅝	13.6	3.98	1.10	4.33	1.81	1.04	1.82	1.17	0.68
3½x3½x 9/16	12.4	3.62	1.08	3.99	1.65	1.05	1.66	1.09	0.68
3½x3½x½	11.1	3.25	1.06	3.64	1.49	1.06	1.50	1.00	0.68
3½x3½x 7/16	9.8	2.87	1.04	3.26	1.32	1.07	1.33	0.91	0.68
3½x3½x⅜	8.5	2.48	1.01	2.87	1.15	1.07	1.16	0.81	0.69
3½x3½x 5/16	7.2	2.09	0.99	2.45	0.98	1.08	0.99	0.71	0.69
3 x3 x 11/16	12.5	3.66	1.00	2.81	1.40	0.88	1.22	0.86	0.58
3 x3 x⅝	11.5	3.36	0.98	2.62	1.30	0.88	1.12	0.81	0.58
3 x3 x 9/16	10.4	3.06	0.95	2.43	1.19	0.89	1.02	0.76	0.58
3 x3 x½	9.4	2.75	0.93	2.22	1.07	0.90	0.92	0.70	0.58
3 x3 x 7/16	8.3	2.43	0.91	1.99	0.95	0.91	0.82	0.64	0.58
3 x3 x⅜	7.2	2.11	0.89	1.76	0.83	0.91	0.72	0.57	0.58
3 x3 x 5/16	6.1	1.78	0.87	1.51	0.71	0.92	0.61	0.50	0.59
3 x3 x¼	4.9	1.44	0.84	1.24	0.58	0.93	0.50	0.42	0.59
2½x2½x 9/16	8.5	2.50	0.83	1.34	0.80	0.73	0.58	0.49	0.48
2½x2½x½	7.7	2.25	0.81	1.23	0.73	0.74	0.52	0.46	0.48
2½x2½x 7/16	6.8	2.00	0.78	1.11	0.65	0.74	0.46	0.42	0.48
2½x2½x⅜	5.9	1.73	0.76	0.98	0.57	0.75	0.41	0.38	0.48
2½x2½x 5/16	5.0	1.47	0.74	0.85	0.48	0.76	0.35	0.33	0.49
2½x2½x¼	4.1	1.19	0.72	0.70	0.39	0.77	0.29	0.28	0.49
2½x2½x 3/16	3.1	0.90	0.69	0.55	0.30	0.78	0.22	0.22	0.49

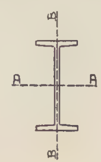
TABLE VII. PROPERTIES OF BETHLEHEM I BEAMS AND BETHLEHEM H GIRDER BEAMS.

Bethlehem I Beams

1 Depth of beam in ins.	2 W't per ft. in lbs.	3 Area of sections in sq. ins.	4 Thickness of web in ins.	5 Width of flange in ins.	6 Moment of Inertia I Axis A-A	7 Moment of Inertia I′ Axis B-B	8 Radius of Gyration r Axis A-A	9 Radius of Gyration r′ Axis B-B	10 Section Modulus S Axis A-A	11 Equivalent Standard Beams.
30	120	35.30	.540	10.50	5239.6	165.0	12.18	2.16	349.3	
28	105	30.88	.500	10.00	4014.1	131.5	11.40	2.06	286.7	
26	90	26.49	.460	9.50	2977.2	101.2	10.60	1.95	229.0	
24	84	24.80	.460	9.25	2381.9	91.1	9.80	1.92	198.5	24″ I 100
24	83	24.59	.520	9.13	2240.9	78.0	9.55	1.78	186.7	24″ I 90
24	73	21.47	.390	9.00	2091.0	74.4	9.87	1.86	174.3	24″ I 80
20	82	24.17	.570	8.89	1559.8	79.9	8.03	1.82	156.0	20″ I 90
20	72	21.37	.430	8.75	1466.5	75.9	8.28	1.88	146.7	20″ I 80
20	69	20.26	.520	8.14	1268.9	51.2	7.91	1.59	126.9	20″ I 75
20	64	18.86	.450	8.07	1222.1	49.8	8.05	1.62	122.2	20″ I 70
20	59	17.36	.375	8.00	1172.2	48.3	8.22	1.66	117.2	20″ I 65
18	59	17.40	.495	7.67	883.3	39.1	7.12	1.50	98.1	18″ I 65
18	54	15.87	.410	7.59	842.0	37.7	7.28	1.54	93.6	18″ I 60
18	52	15.24	.375	7.55	825.0	37.1	7.36	1.56	91.7	
18	48½	14.25	.320	7.50	798.3	36.2	7.48	1.59	88.7	18″ I 55
15	71	20.95	.520	7.50	796.2	61.3	6.16	1.71	106.2	15″ I 80
15	64	18.81	.605	7.19	664.9	41.9	5.95	1.49	88.6	15″ I 70
15	54	15.88	.410	7.00	610.0	38.3	6.20	1.55	81.3	15″ I 60
15	46	13.52	.440	6.81	484.8	25.2	5.99	1.36	64.6	15″ I 50
15	41	12.02	.340	6.71	456.7	24.0	6.16	1.41	60.9	15″ I 45
15	38	11.27	.290	6.66	442.6	23.4	6.27	1.44	59.0	15″ I 42
12	36	10.61	.310	6.30	269.2	21.3	5.04	1.42	44.9	12″ I 40
12	32	9.44	.335	6.20	228.5	16.0	4.92	1.30	38.1	12″ I 35
12	28½	8.42	.250	6.12	216.2	15.3	5.07	1.35	36.0	12″ I 31½
10	28½	8.34	.390	5.99	134.6	12.1	4.02	1.21	26.9	10″ I 30
10	23½	6.94	.250	5.85	122.9	11.2	4.21	1.27	24.6	10″ I 25
9	24	7.04	.365	5.55	92.1	8.8	3.62	1.12	20.5	9″ I 25
9	20	6.01	.250	5.44	85.1	8.2	3.76	1.17	18.9	9″ I 21
8	19½	5.78	.325	5.32	60.6	6.7	3.24	1.08	15.1	8″ I 20½
8	17½	5.18	.250	5.25	57.4	6.4	3.33	1.11	14.3	8″ I 18

Bethlehem H Girder Beams

1 Depth of beam in ins.	2 W't per ft. in lbs.	3 Area of sections in sq. ins.	4 Thickness of web in ins.	5 Width of flange in ins.	6 Moment of Inertia I Axis A-A	7 Moment of Inertia I′ Axis B-B	8 Radius of Gyration r Axis A-A	9 Radius of Gyration r′ Axis B-B	10 Section Modulus S Axis A-A	11 Equivalent Standard Beams.
30	200	58.71	.75	15.00	9150.6	630.2	12.48	3.28	610.0	
30	180	53 00	.69	13.00	8194.5	433.3	12.43	2.86	546.3	
28	180	52.86	.69	14.35	7264.7	533.3	11.72	3.18	518.9	
28	165	48.47	.66	12.50	6562.7	371.9	11.64	2.77	468.8	
26	160	46.91	.63	13.60	5620.8	435.7	10.95	3.05	432.4	
26	150	43 94	.63	12.00	5153.9	314.6	10.83	2.68	396.5	2—24″ I 100
24	140	41.16	.60	13.00	4201.4	346.9	10.10	2.90	350.1	2—24″ I 80
24	120	35 38	.53	12.00	3607.3	249.4	10.10	2.66	300.6	2—20″ I 85
20	140	41.19	.64	12.50	2934.7	348.9	8.44	2.91	293.5	2—20″ I 80
20	112	32.81	.55	12.00	2342.1	239.3	8.45	2.70	234.2	2—20″ I 65
18	92	27.12	.48	11.50	1591.4	182.6	7.66	2.59	176.8	2—18″ I 55
15	140	41.27	.80	11.75	1592.7	331.0	6.21	2.83	212.4	2—15″ I 80
15	104	30.50	.60	11.25	1220.1	213.0	6.32	2.64	162.7	2—15″ I 60
15	73	21.49	.43	10.50	883 4	123.2	6.41	2.39	117.8	2—15″ I 42
12	70	20.58	.46	10.00	538.8	114.7	5.12	2.36	89.8	2—12″ I 40
12	55	16.18	.37	9.75	432.0	81.1	5.17	2.24	72.0	2—12″ I 31½
10	44	12.95	.31	9.00	244.2	57.3	4.34	2.10	48.8	2—10″ I 25
9	38	11.22	.30	8.50	170.9	44.1	3.90	1.98	38.0	2— 9″ I 21
8	32½	9.54	.29	8.00	114.4	32.9	3.46	1.86	28.6	2— 8″ I 18



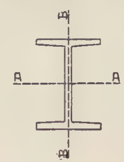


TABLE VIII. PROPERTIES OF BETHLEHEM H COLUMNS.

1	2	3	4	5	6	7	8	9	10
W'ght per foot lbs.	Area of section sq. in	Depth of section ins.	Thickness of web ins.	Width of flange ins.	Moments of Inertia I axis AA	Moments of Inertia I' axis BB	Radius of Gyration r axis AA	Radius of Gyration r' axis BB	Section Modulus S
				14 in. H Columns.					
83.5	24.46	13¾	.43	13.92	884.9	294.5	6.01	3.47	128.7
91.0	26.76	13⅞	.47	13.96	976.8	325.4	6.04	3.49	140.8
99.0	29.06	14	.51	14.00	1070.6	356.9	6.07	3.50	153.0
106.5	31.38	14⅛	.55	14.04	1166.6	387.8	6.10	3.52	165.2
114.5	33.70	14¼	.59	14.08	1264.5	420.3	6.13	3.53	177.5
122.5	36.04	14⅜	.63	14.12	1364.6	453.4	6.16	3.55	189.9
130.5	38.38	14½	.67	14.16	1466.7	486.9	6.18	3.56	202.3
138.0	40.59	14⅝	.70	14.19	1568.4	519.7	6.21	3.58	214.5
146.0	42.95	14¾	.74	14.23	1674.7	554.4	6.24	3.59	227.1
154.0	45.33	14⅞	.78	14.27	1783.3	589.5	6.27	3.61	239.8
162.0	47.71	15	.82	14.31	1894.0	626.1	6.30	3.62	252.5
170.5	50.11	15⅛	.86	14 35	2007.0	662.3	6.33	3.64	265.4
178.5	52.51	15¼	.90	14.39	2122.3	699.0	6.36	3.65	278.3
186.5	54.92	15⅜	.94	14.43	2239.8	736.3	6.39	3.66	291.4
195.0	57.35	15½	.98	14.47	2359.7	774.2	6.41	3.67	304.5
203.5	59.78	15⅝	1.02	14.51	2481.9	812.6	6.44	3.69	317.7
211.0	62.07	15¾	1.05	14.54	2603.3	849.8	6.48	3.70	330.6
219.5	64.52	15⅞	1.09	14.58	2730.2	889.3	6.51	3.71	344.0
227.5	66.98	16	1.13	14.62	2859.6	929.4	6.53	3.73	357.5
236.0	69.45	16⅛	1.17	14.66	2991.5	970.0	6.56	3.74	371.0
244.5	71.94	16¼	1.21	14.70	3125.8	1011.3	6.59	3.75	384.7
253.0	74.43	16⅜	1.25	14.74	3262.7	1053.2	6.62	3.76	398.5
261.5	76.93	16½	1.29	14.78	3402.1	1095.6	6.65	3.77	412.4
270.0	79.44	16⅝	1.33	14.82	3544.1	1138.7	6.68	3.79	426.4
278.5	81.97	16¾	1.37	14.86	3688.8	1182.4	6.71	3.80	440.5
287.5	84.50	16⅞	1.41	14.90	3836.1	1226.7	6.74	3.81	454.7
				12 in. H Columns.					
64.5	19.00	11¾	.39	11.92	499.0	168.6	5.13	2.98	84.9
71.5	20 96	11⅞	.43	11.96	556.6	188.2	5.15	3.00	93.7
78.0	22.94	12	.47	12.00	615.6	208.1	5.18	3.01	102.6
84.5	24 92	12⅛	.51	12.04	676.1	228.5	5.21	3.03	111.5
91.5	26.92	12¼	.55	12.08	738.1	249.2	5.24	3.04	120.5
98.5	28.92	12⅜	.59	12.12	801.7	270.1	5.27	3.06	129.6
105.0	30.94	12½	.63	12.16	866.8	291.7	5.30	3.07	138.6
112.0	32 96	12⅝	.67	12.20	933.4	313.6	5.33	3.08	147.9
118.5	34.87	12¾	.70	12.23	1000.0	335 0	5.36	3.10	156.9
125.5	36 91	12⅞	.74	12.27	1069.8	357.7	5.38	3.11	166.2
132.5	38.97	13	.78	12.31	1141.3	380.7	5.41	3.13	175.6
139.5	41.03	13⅛	.82	12.35	1214.5	404.1	5.44	3.14	185.0
146.5	43 10	13¼	.86	12.39	1289.4	428.0	5.47	3.15	194.6
153.5	45.19	13⅜	.90	12.43	1366.0	452.2	5.50	3.16	204.3
161.0	47.28	13½	.94	12.47	1444.3	477.0	5.53	3.18	214.0

TABLE VIII-A.—PROPERTIES OF BETHLEHEM H COLUMNS

1	2	3	4	5	6	7	8	9	10
W'ght per foot lbs.	Area of section sq. in	Depth of section ins.	Thick-ness of web ins.	Width of flange ins.	Moments of Inertia I axis AA	I' axis BB	Radius of Gyration r axis AA	r' axis BB	Sec-tion Modu-lus S
				10 in. H Columns.					
49.0	14.37	9⅞	.36	9.97	263.5	89.1	4.28	2.49	53.4
54.0	15.91	10	.39	10.00	296.8	100.4	4.32	2.51	59.4
59.5	17.57	10⅛	.43	10.04	331.9	112.2	4.35	2.53	65.6
65.5	19.23	10¼	.47	10.08	368.0	124.2	4.37	2.54	71.8
71.0	20.91	10⅜	.51	10.12	405.2	136.5	4.40	2.56	78.1
77.0	22.59	10½	.55	10.16	443.6	149.1	4.43	2.57	84.5
82.5	24.29	10⅝	.59	10.20	483.0	162.0	4.46	2.58	90.9
88.5	25.99	10¾	.63	10.24	523.5	175.1	4.49	2.60	97.4
94.0	27.71	10⅞	.67	10.28	565.2	188.6	4.52	2.61	103.9
99.5	29.32	11	.70	10.31	607.0	201.7	4.55	2.62	110.4
105.5	31.06	11⅛	.74	10.35	651.0	215.6	4.58	2.64	117.0
111.5	32.80	11¼	.78	10.39	696.2	229.9	4.61	2.65	123.8
117.5	34.55	11⅜	.82	10.43	742.7	244.4	4.64	2.66	130.6
123.5	36.32	11½	.86	10.47	790.4	259.3	4.67	2.67	137.5
				8 in. H Columns.					
32.0	9.17	7⅞	.31	8.00	105.7	35.8	3.40	1.98	26.9
34.5	10.17	8	.31	8.00	121.5	41.1	3.46	2.01	30.4
39.0	11.50	8⅛	.35	8.04	139.5	47.2	3.48	2.03	34.3
43.5	12.83	8¼	.39	8.08	158.3	53.4	3.51	2.04	38.4
48.0	14.18	8⅜	.43	8.12	177.7	59.8	3.54	2.05	42.4
53.0	15.53	8½	.47	8.16	197.8	66.3	3.57	2.07	46.5
57.5	16.90	8⅝	.51	8.20	218.6	73.1	3.60	2.08	50.7
62.0	18.27	8¾	.55	8.24	240.2	80.0	3.63	2.09	54.9
67.0	19.66	8⅞	.59	8.28	262.5	87.1	3.65	2.11	59.2
71.5	21.05	9	.63	8.32	285.6	94.4	3.68	2.12	63.5
76.5	22.46	9⅛	.67	8.36	309.5	101.9	3.71	2.13	67.8
81.0	23.78	9¼	.70	8.39	333.5	109.2	3.75	2.14	72.1
85.5	25.20	9⅜	.74	8.43	359.0	117.2	3.77	2.16	76.6
90.5	26.64	9½	.78	8.47	385.3	125.1	3.80	2.17	81.1

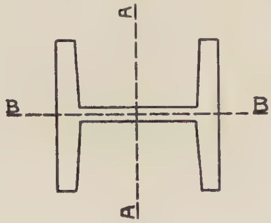


TABLE IX. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

American Standard and Special I Beams

These safe loads include the weight of the beam and are figured for a maximum fibre stress of 16,000 lbs. per sq. in. and safe deflection.

When using safe loads above dotted line, the web must be stiffened within every 25 times the width of the flange, to prevent web crippling.

For safe loads below the heavy lines, the deflections will exceed the allowable limit for plastered ceilings=1-360 span.

Depth of Beam in.	24″ I					20″ I								18″ I				15″ I			
Weight per ft. in lbs.	80	85	90	95	100	65	70	75	80	85	90	95	100	55	60	65	70	42	45	50	55
Span 10 ft.	92.8	96.3	99.5	102.6	105.8	62.3	65.0	67.7	78.2	80.4	83.1	85.7	88.3	47.2	49.9	52.2	54.6	31.4	32.4	34.4	36.3
11	84.3	87.6	90.4	93.3	96.1	56.7	59.1	61.5	71.1	73.1	75.5	77.9	80.3	42.9	45.3	47.5	49.6	28.6	29.5	31.2	33.0
12	77.3	80.3	82.9	85.5	88.1	52.0	54.2	56.4	65.2	67.0	69.2	71.4	73.6	39.3	41.6	43.5	45.5	26.2	27.0	28.6	30.3
13	71.4	74.1	76.5	78.9	81.3	48.0	50.0	52.0	60.2	61.9	63.9	65.9	67.9	36.3	38.4	40.2	42.0	24.2	24.9	26.4	27.5
14	66.3	68.8	71.1	73.3	75.5	44.6	46.5	48.3	55.9	57.4	59.3	61.2	63.1	33.7	35.6	37.3	39.0	22.4	23.1	24.5	25.9
15	61.9	64.2	66.3	68.4	70.5	41.6	43.2	45.0	52.1	53.6	55.2	57.1	58.8	31.4	33.2	34.8	36.4	20.9	21.6	22.8	24.2
16	58.0	60.2	62.2	64.1	66.1	39.0	40.6	45.2	48.9	50.2	51.8	53.5	55.2	29.5	31.2	32.6	34.1	19.6	20.2	21.4	22.6
17	54.6	56.6	58.5	60.3	62.2	36.7	38.2	39.8	46.0	47.3	48.8	50.4	52.0	27.7	29.3	30.6	32.1	18.5	19.0	20.2	21.3
18	51.6	53.4	55.2	57.0	58.7	34.6	36.0	37.5	43.4	44.6	46.0	47.6	49.0	26.2	27.7	29.0	30.3	17.4	18.0	19.0	20.0
19	48.8	50.7	52.4	54.0	55.7	32.8	34.2	35.6	41.1	37.0	43.7	45.1	46.5	24.8	26.2	27.5	28.7	16.5	17.0	18.0	19.1
20	46.4	48.1	49.7	51.3	52.9	31.2	32.5	33.8	39.1	40.2	41.5	42.8	44.1	23.6	24.9	26.1	27.3	15.7	16.2	17.1	18.1
21	44.2	45.8	47.4	48.8	50.4	29.7	30.9	32.2	37.2	38.3	39.5	40.8	42.0	22.4	23.7	24.8	26.0	15.0	15.4	16.3	17.3
22	42.2	43.8	45.2	46.6	48.1	28.3	29.5	30.7	35.5	36.5	37.7	38.9	40.1	21.4	22.7	23.7	24.8	14.3	14.7	15.6	16.5
23	40.3	41.9	43.3	44.6	46.0	27.1	28.3	29.4	34.0	35.0	36.1	37.3	38.4	20.5	21.7	22.7	23.7	13.7	14.1	14.9	15.8
24	38.7	40.1	41.4	42.7	44.0	26.0	27.0	28.1	32.6	33.5	34.5	35.7	36.8	19.6	20.8	21.7	22.7	13.1	13.5	14.3	15.1
25	37.1	38.5	39.8	41.0	42.3	24.9	26.0	27.0	31.3	32.1	33.2	34.3	35.3	18.9	19.9	20.9	21.8	12.6	12.9	13.7	14.5
26	35.7	37.0	38.3	39.5	40.7	24.0	25.0	26.0	30.1	30.9	31.9	33.0	34.0	18.1	19.2	20.1	21.0	12.1	12.5	13.2	14.0
27	34.4	35.7	36.8	38.0	39.2	23.1	24.1	25.1	28.9	29.8	30.8	31.7	32.7	17.5	18.4	19.3	20.2	11.6	12.0	12.7	13.5
28	33.1	34.4	35.5	36.6	37.8	22.3	23.2	24.1	27.9	28.7	29.6	30.6	31.5	16.8	17.8	18.6	19.5	11.2	11.6	12.3	13.0
29	32.0	33.2	34.3	35.4	36.5	21.5	22.4	24.2	27.0	27.7	28.6	29.5	30.4	16.3	17.2	18.0	18.8	10.8	11.2	11.8	12.5
30	30.9	32.1	33.1	34.2	35.2	20.8	21.6	22.5	26.0	26.8	27.6	28.5	29.4	15.7	16.6	17.4	18.2	10.5	10.8	11.5	12.1
31	29.9	31.1	32.1	33.1	34.1	20.1	21.0	21.8	25.3	25.9	26.8	27.6	28.5	15.2	16.1	16.8	17.6	10.1	10.4	11.1	11.7
32	29.0	30.1	31.1	32.1	33.0	19.5	20.3	21.1	24.4	25.1	26.0	26.8	27.6	14.7	15.6	16.3	17.1	9.8	10.1	10.7	11.3
33	28.1	29.2	30.1	31.1	32.0	18.9	19.7	20.5	23.7	24.3	25.1	26.0	26.8	14.3	15.1	15.8	16.5	9.5	9.8	10.4	11.0
34	27.3	28.3	29.3	30.2	31.1	18.3	19.1	19.9	23.0	23.7	24.4	25.2	26.0	13.9	14.7	15.4	16.0	9.2	9.5	10.1	10.7
35	26.5	27.5	28.4	29.3	30.2	17.8	18.6	19.8	22.3	23.0	23.7	24.5	25.2	13.5	14.2	14.9	15.6	9.0	9.3	9.8	10.4
36	25.8	26.7	27.6	28.5	29.3	17.3	18.1	18.8	21.7	22.3	23.1	23.8	24.5	13.1	13.8	14.5	15.2	8.7	9.0	9.5	10.1

TABLE X. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

American Standard and Special I Beams

These safe loads include the weight of the beams and are figured for a maximum fibre stress of 16,000 lbs. per sq. in. and safe deflection.

When using safe loads above the dotted line, the web must be stiffened within every 25 times the width of the flange, to prevent web crippling.

For safe loads below the heavy lines, the deflections will exceed the allowable limit for plastered ceilings=1/360 span.

Depth of Beam in.	15 in. I								
Wt. per ft. in lbs.	60	65	70	75	80	85	90	95	100
Span									
10	43.3	45.2	47.2	49.1	56.1	58.0	60.0	61.9	63.9
11	39.4	41.1	42.9	44.7	51.0	52.7	54.5	56.3	58.1
12	36.1	37.7	39.3	41.0	47.0	48.3	50.0	51.6	53.2
13	33.3	34.8	36.3	37.8	43.5	44.6	46.1	47.6	49.1
14	30.9	32.3	33.6	35.1	40.4	41.5	42.9	44.3	45.7
15	28.9	30.1	31.4	32.7	37.7	38.7	40.0	41.3	42.7
16	27.1	28.2	29.4	30.7	35.3	36.3	37.6	38.7	40.0
17	25.5	26.6	27.7	28.8	33.3	34.2	35.3	36.5	37.6
18	24.1	25.0	26.1	27.2	31.4	32.8	33.4	34.4	35.5
19	22.8	23.8	24.8	25.8	29.8	30.6	31.6	32.6	33.7
20	21.6	22.6	23.5	24.5	28.3	29.0	30.0	31.0	32.0
21	20.6	21.5	22.4	23.4	26.9	27.6	28.6	29.5	30.5
22	19.7	20.5	21.4	22.3	25.7	26.4	27.3	28.2	29.1
23	18.8	19.6	20.5	21.3	24.6	25.3	26.1	27.0	27.8
24	18.0	18.8	19.6	20.4	23.6	24.6	25.0	25.8	26.6
25	17.3	18.1	18.8	19.6	22.6	23.2	24.0	24.8	25.6
26	16.7	17.4	18.1	18.9	21.8	22.3	23.1	23.8	24.6
27	16.0	16.7	17.5	18.2	20.9	21.5	22.2	22.9	23.7
28	15.5	16.1	16.9	17.6	20.2	20.7	21.4	22.1	22.8
29	14.9	15.6	16.3	16.9	19.5	20.0	20.7	21.4	22.0
30	14.4	15.1	15.7	16.4	18.9	19.3	20.0	20.6	21.3
31	14.0	14.6	15.2	15.8	18.2	18.7	19.3	20.0	20.6
32	13.5	14.1	14.7	15.4	17.7	18.1	18.7	19.4	20.0
33	13.1	13.7	14.3	14.9	17.1	17.6	18.2	18.8	19.4
34	12.7	13.3	13.9	14.5	16.6	17.1	17.6	18.2	18.8
35	12.4	12.9	13.5	14.0	16.2	16.6	17.1	17.7	18.2
36	12.0	12.6	13.1	13.6	15.7	16.1	16.7	17.2	17.8

Depth of Beam in.	12 in. I						10 in. I			
Wt. per ft. in lbs.	31½	35	40	45	50	55	25	30	35	40
Span										
8	24.0	25.3	27.3	31.7	33.7	35.6	16.2	17.9	19.5	21.1
9	21.3	22.5	24.3	28.2	30.0	31.7	14.4	15.9	17.3	18.8
10	19.2	20.3	23.9	25.4	27.0	28.5	13.0	14.3	15.6	16.9
11	17.4	18.4	21.7	23.1	24.5	26.0	11.8	13.0	14.2	15.4
12	16.0	16.9	19.9	21.2	22.5	23.8	10.8	11.9	13.0	14.1
13	14.8	15.6	18.4	19.5	20.7	22.0	10.0	11.0	12.0	13.0
14	13.7	14.5	17.1	18.1	19.2	20.3	9.3	10.2	11.1	12.1
15	12.8	13.5	15.9	16.9	17.9	19.0	8.7	9.5	10.4	11.6
16	12.0	12.6	14.9	15.8	16.8	17.8	8.1	8.9	9.7	10.5
17	11.3	11.9	14.1	14.9	15.8	16.8	7.7	8.4	9.2	9.9
18	10.7	11.3	13.3	14.1	14.9	15.3	7.2	7.9	8.7	9.4
19	10.1	10.6	12.6	13.4	14.1	15.0	6.9	7.5	8.2	8.9
20	9.6	10.1	11.9	12.7	13.4	14.2	6.5	7.1	7.8	8.5
21	9.1	9.7	11.4	12.1	12.8	13.6	6.2	6.8	7.4	8.1
22	8.7	9.2	10.9	11.5	12.2	13.0	5.9	6.5	7.1	7.7
23	8.3	8.8	10.4	11.0	11.7	12.4	5.7	6.2	6.8	7.4
24	8.0	8.4	10.0	10.6	11.2	11.9	5.4	6.0	6.5	7.0
25	7.7	8.1	9.6	10.1	10.8	11.4	5.2	5.7	6.2	6.8
26	7.4	7.8	9.2	9.8	10.4	11.0	5.0	5.5	6.0	6.5
27	7.1	7.5	8.8	9.4	10.0	10.6	4.8	5.3	5.8	6.3
28	6.8	7.2	8.5	9.1	9.6	10.2	4.6	5.1	5.6	6.0
29	6.6	7.0	8.2	8.7	9.3	9.8	4.5	4.9	5.3	5.8
30	6.4	6.8	8.0	8.5	9.0	9.0	4.3	4.8	5.2	5.6
31	6.2	6.5	7.7	8.2	8.7	9.2	4.2	4.6	5.0	5.5
32	6.0	6.3	7.5	7.9	8.4	8.9	4.1	4.5	4.9	5.3
33	5.8	6.1	7.2	7.7	8.1	8.6	4.0	4.3	4.7	5.1
34	5.6	6.0	7.0	7.5	7.9	8.4	3.8	4.2	4.6	4.9

TABLE XI. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

American Standard and Special I Beams

These safe loads include the weight of the beam and are figured for a maximum fibre stress of 16,000 pounds per sq. in. and safe deflection.

When using safe loads above dotted line, the web must be tiffened within every 25 times the width of the flange to prevent web crippling.

For safe loads below the heavy lines, the deflections will exceed the allowable limit for plastered ceilings=1/360 span.

Depth of Beam in.	9″ I				8″ I				7″ I			6″ I			5″ I		
Wt. per ft. in lbs.	21	25	30	35	18	20.5	23.0	25.5	15	17.5	20	12¼	14.75	17.25	9¾	12.25	14.75
Span 4 ft.	25.2	27.2	30.1	33.0	18.9	20.1	21.4	22.7	13.8	14.9	16.1	9.7	10.7	11.6	6.4	7.3	8.1
5	20.2	21.8	24.1	26.4	15.2	16.0	17.1	18.2	11.0	11.9	12.8	7.7	8.5	9.3	5.2	5.8	6.5
6	16.8	18.1	20.1	22.0	12.6	13.4	14.2	15.1	9.2	10.0	10.7	6.5	7.1	7.8	4.3	4.8	5.4
7	14.4	15.5	17.2	18.9	10.8	11.5	12.2	13.0	7.9	8.5	9.2	5.5	6.1	6.6	3.7	4.2	4.6
8	12.5	13.6	15.1	16.5	9.5	10.1	10.7	11.4	6.9	7.4	8.0	4.8	5.3	5.8	3.2	3.6	4.0
9	11.1	12.1	13.4	13.6	8.4	8.9	9.5	10.1	6.1	6.6	7.1	4.3	4.7	5.1	2.9	3.2	3.6
10	10.0	10.9	12.0	13.2	7.6	8.0	8.6	9.1	5.5	5.9	6.4	3.9	4.2	4.6	2.6	2.9	3.2
11	9.1	9.9	10.9	12.0	6.9	7.3	7.8	8.3	5.0	5.4	5.8	3.5	3.9	4.2	2.3	2.7	2.9
12	8.4	9.0	10.0	11.0	6.3	6.7	7.1	7.6	4.6	4.9	5.3	3.2	3.5	3.9	2.1	2.4	2.7
13	7.7	8.4	9.3	10.2	5.8	6.2	6.6	7.0	4.2	4.6	4.9	3.0	3.3	3.6	2.0	2.2	2.5
14	7.2	7.8	8.6	9.4	5.4	5.7	6.1	6.5	3.9	4.3	4.6	2.8	3.0	3.3	1.8	2.1	2.3
15	6.7	7.2	8.0	8.8	5.1	5.3	5.7	6.0	3.7	4.0	4.3	2.6	2.8	3.1	1.7	1.9	2.1
16	6.3	6.8	7.5	8.3	4.7	5.0	5.3	5.7	3.4	3.7	4.0	2.4	2.7	2.9	1.6	1.8	2.0
17	5.9	6.4	7.1	7.8	4.5	4.7	5.0	5.3	3.2	3.5	3.8	2.3	2.5	2.7	1.5	1.7	1.9
18	5.6	6.0	6.7	7.4	4.2	4.5	4.7	5.0	3.1	3.3	3.6	2.1	2.4	2.6	1.4	1.6	1.8
19	5.3	5.7	6.3	7.0	4.0	4.2	4.5	4.8	2.9	3.1	3.4	2.0	2.2	2.5	1.4	1.5	1.7
20	5.0	5.4	6.0	6.6	3.8	4.0	4.3	4.5	2.8	3.0	3.2	1.9	2.1	2.4	1.3	1.4	1.6
21	4.8	5.2	5.7	6.3	3.6	3.8	4.1	4.3	2.6	2.8	3.1	1.8	2.0	2.2	1.2	1.4	1.5
22	4.6	5.0	5.5	6.0	3.4	3.6	3.9	4.1	2.5	2.7	2.9	1.8	1.9	2.1	1.2	1.3	1.5
23	4.4	4.8	5.2	5.8	3.3	3.5	3.7	3.9	2.4	2.6	2.8	1.7	1.8	2.0	1.1	1.3	1.4
24	4.2	4.5	5.0	5.5	3.2	3.3	3.6	3.8	2.3	2.5	2.7	1.6	1.8	1.9	1.1	1.2	1.3
25	4.0	4.4	4.8	5.3	3.0	3.2	3.4	3.6	2.2	2.4	2.6	1.5	1.7	1.9	1.0	1.2	1.3
26	3.9	4.2	4.6	5.1	2.9	3.1	3.3	3.5	2.1	2.3	2.5	1.5	1.6	1.8	1.0	1.1	1.2
27	3.7	4.0	4.5	4.9	2.8	3.0	3.2	3.4	2.0	2.2	2.4	1.4	1.6	1.7	.9	1.1	1.2
28	3.6	3.9	4.3	4.7	2.7	2.9	3.1	3.2	2.0	2.1	2.3	1.4	1.5	1.7	.9	1.0	1.2
29	3.5	3.7	4.2	4.6	2.6	2.8	2.9	3.1	1.9	2.1	2.2	1.3	1.5	1.6	.9	1.0	1.1
30	3.4	3.6	4.0	4.4	2.5	2.7	2.9	3.0	1.8	2.0	2.0	1.3	1.4	1.5	.9	1.0	1.1
31	3.2	3.5	3.9	4.3	2.4	2.6	2.8	2.9	1.8	1.9	2.0	1.3	1.4	1.5	.8	.9	1.0

TABLE XII. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS

American Standard and Special Channels

These safe loads include the weight of the channels and are figured for a maximum fibre stress of 16,000 lbs. per sq. in. and safe deflection.

When using safe loads above the dotted line, the web must be stiffened within every 25 times the width of the flange to prevent web crippling.

For safe loads below the heavy lines, the deflections will exceed the allowable limit for plastered ceilings=1/360 span.

Depth of Beam in.	15 in. [						12 in. [					10 in. [					9 in. [			
Wt. per ft. in lbs.	33	35	40	45	50	55	20½	25	30	35	40	15	20	25	30	35	13¼	15	20	25
Span 4	55.5	57.0	61.7	66.6	71.6	76.4	28.5	32.0	35.8	39.8	43.7	17.9	21.0	24.2	27.4	30.8	14.0	15.1	18.0	20.9
5	44.5	45.5	49.5	53.4	57.3	61.1	22.8	25.6	28.7	31.9	35.0	14.3	16.7	19.4	22.0	24.6	11.2	12.0	14.4	16.8
6	37.0	38.0	41.1	44.5	47.7	50.9	19.0	21.4	23.9	26.6	29.2	11.9	13.9	16.2	18.3	20.5	9.34	10.0	12.0	13.9
7	31.8	32.5	35.2	38.1	40.9	43.7	16.3	18.3	20.5	22.8	25.0	10.2	11.9	13.8	15.7	17.6	8.01	8.61	10.3	12.0
8	27.8	28.4	30.8	33.4	35.8	38.2	14.3	16.0	17.9	19.9	21.8	8.93	10.5	12.1	13.7	15.4	7.01	7.53	9.0	10.4
9	24.7	25.3	27.4	29.6	31.8	34.0	12.7	14.2	15.9	17.7	19.4	7.95	9.30	10.8	12.2	13.7	6.23	6.69	8.00	9.31
10	22.2	22.7	24.7	26.6	28.6	30.6	11.4	12.8	14.3	15.9	17.5	7.14	8.39	9.70	11.0	12.3	5.61	6.02	7.20	8.38
11	20.2	20.7	22.5	24.2	26.0	27.8	10.3	11.6	13.1	14.5	15.9	6.49	7.63	8.82	10.0	11.2	5.10	5.48	6.55	7.62
12	18.5	18.9	20.6	22.2	23.8	25.5	9.5	10.6	11.9	13.3	14.6	5.95	7.00	8.08	9.2	10.3	4.68	5.02	6.00	6.98
13	17.1	17.5	19.0	20.5	22.0	23.5	8.8	9.8	11.0	12.3	13.5	5.49	6.46	7.46	8.5	9.5	4.32	4.63	5.54	6.44
14	15.9	16.2	17.6	19.0	20.4	21.8	8.1	9.1	10.2	11.4	12.5	5.10	6.00	6.93	7.9	8.8	4.01	4.30	5.14	5.98
15	14.8	15.1	16.4	17.7	19.0	20.3	7.5	8.5	9.5	10.6	11.6	4.76	5.60	6.47	7.3	8.2	3.74	4.02	4.80	5.58
16	13.9	14.2	15.4	16.6	17.9	19.1	7.1	8.0	8.9	9.9	10.9	4.46	5.25	6.06	6.9	7.7	3.51	3.76	4.50	5.23
17	13.1	13.4	14.5	15.7	16.8	17.9	6.7	7.5	8.4	9.4	10.3	4.20	4.94	5.71	6.5	7.2	3.30	3.54	4.23	4.93
18	12.3	12.6	13.7	14.8	15.9	17.0	6.3	7.1	7.9	8.8	9.7	3.96	4.66	5.39	6.1	6.8	3.12	3.35	4.00	4.65
19	11.7	12.0	13.0	14.0	15.0	16.1	6.0	6.7	7.5	8.3	9.2	3.76	4.42	5.11	5.8	6.5	2.95	3.17	3.79	4.41
20	11.1	11.3	12.3	13.3	14.3	15.3	5.7	6.4	7.1	7.9	8.7	3.57	4.20	4.85	5.5	6.2	2.81	3.01	3.60	4.19
21	10.6	10.8	11.7	12.7	13.6	14.5	5.4	6.1	6.8	7.6	8.3	3.40	4.00	4.62	5.2	5.9	2.67	2.87	3.43	3.99
22	10.1	10.3	11.2	12.1	13.0	13.9	5.2	5.8	6.5	7.2	8.0	3.24	3.81	4.41	5.0	5.6	2.55	2.74	3.27	3.81
23	9.7	9.9	10.7	11.6	12.4	13.3	4.9	5.6	6.2	6.9	7.6	3.10	3.65	4.22	4.8	5.3	2.44	2.62	3.13	3.64
24	9.3	9.5	10.3	11.1	11.9	12.7	4.7	5.3	6.0	6.6	7.3	2.97	3.50	4.04	4.6	5.1	2.34	2.51	3.00	3.49
25	8.9	9.1	9.9	10.7	11.4	12.2	4.6	5.1	5.7	6.4	7.0	2.85	3.36	3.88	4.4	4.9	2.24	2.41	2.88	3.35
26	8.5	8.7	9.5	10.2	11.0	11.8	4.4	4.9	5.5	6.1	6.7	2.74	3.23	3.73	4.2	4.7	2.16	2.32	2.77	3.22
27	8.2	8.4	9.1	9.9	10.6	11.3	4.2	4.7	5.3	5.9	6.5	2.64	3.11	3.59	4.1	4.6	2.08	2.23	2.67	3.10
28	7.9	8.1	8.8	9.5	10.2	10.9	4.1	4.6	5.1	5.7	6.2	2.55	3.00	3.46	3.9	4.4	2.00	2.15	2.58	2.95
29	7.7	7.8	8.5	9.2	9.9	10.0	3.9	4.4	4.9	5.5	6.0	2.46	2.89	3.34	3.8	4.2	1.93	2.08	2.48	2.89
30	7.4	7.1	7.7	8.3	8.9	9.5	3.8	4.3	4.8	5.3	5.8	2.38	2.80	3.23	3.7	4.1	1.87	2.01	2.40	2.79

TABLE XIII. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

American Standard and Special Channels

These safe loads include the weight of the channel and are figured for a maximum fibre stress of 16,000 pounds per sq. in. and safe deflection.

When using safe loads above the dotted lines, the web must be stiffened within every 25 times the width of the flange to prevent web crippling.

For safe loads below the heavy lines, the deflections will exceed the allowable limit for plastered ceilings=1/360 span.

Depth of Channel	8 in. [					7 in. [					6 in. [				5 in. [		
Weight per ft. in lbs.	11¼	13¾	16¼	18¾	21¼	9¾	12¼	14¾	17¼	19¾	8	10½	13	15½	6½	9	11½
Span 3 ft.	14.3	16.0	17.7	19.4	21.2	11.1	12.3	13.4	15.3	16.8	7.7	8.9	10.2	11.6	5.2	6.3	7.4
4	10.8	12.0	13.3	14.6	15.9	8.03	9.21	10.3	11.5	12.6	5.77	6.72	7.70	8.68	3.95	4.73	5.55
5	8.61	9.60	10.6	11.7	12.7	6.68	7.36	8.28	9.19	10.1	4.62	5.37	6.16	6.94	3.16	3.79	4.44
6	7.18	8.00	8.87	9.74	10.6	5.57	6.14	6.90	7.66	8.42	3.85	4.48	5.13	5.79	2.63	3.16	3.70
7	6.15	6.95	7.60	8.35	9.10	4.77	5.26	5.91	6.57	7.22	3.30	3.84	4.40	4.96	2.26	2.70	3.17
8	5.38	6.00	6.65	7.30	7.96	4.18	4.60	5.17	5.74	6.32	2.89	3.36	3.85	4.34	1.98	2.37	2.77
9	4.78	5.33	5.91	6.49	7.07	3.71	4.09	4.60	5.11	5.62	2.57	2.99	3.42	3.86	1.76	2.10	2.46
10	4.31	4.80	5.32	5.84	6.37	3.34	3.68	4.14	4.60	5.05	2.31	2.69	3.08	3.47	1.58	1.89	2.22
11	3.91	4.36	4.83	5.31	5.80	3.04	3.35	3.76	4.18	4.60	2.10	2.44	2.80	3.15	1.44	1.72	2.02
12	3.59	4.00	4.43	4.87	5.30	2.78	3.07	3.45	3.83	4.21	1.93	2.24	2.56	2.89	1.32	1.57	1.85
13	3.31	3.69	4.09	4.50	4.90	2.57	2.83	3.18	3.53	3.89	1.78	2.06	2.37	2.67	1.22	1.45	1.70
14	3.08	3.42	3.80	4.17	4.55	2.39	2.63	2.95	3.28	3.61	1.65	1.92	2.20	2.48	1.13	1.35	1.58
15	2.87	3.20	3.54	3.89	4.24	2.23	2.45	2.76	3.06	3.37	1.54	1.79	2.05	2.31	1.05	1.26	1.48
16	2.69	3.00	3.32	3.65	3.98	2.09	2.30	2.59	2.87	3.16	1.44	1.68	1.92	2.17	.99	1.18	1.38
17	2.53	2.82	3.13	3.44	3.74	1.96	2.16	2.43	2.70	2.97	1.36	1.58	1.81	2.04	.93	1.11	1.30
18	2.39	2.66	2.95	3.24	3.54	1.86	2.04	2.30	2.55	2.81	1.28	1.49	1.71	1.93	.88	1.05	1.23
19	2.27	2.52	2.80	3.07	3.35	1.76	1.94	2.18	2.42	2.66	1.22	1.41	1.62	1.82	.83	.99	1.17
20	2.15	2.40	2.66	2.92	3.18	1.67	1.84	2.07	2.30	2.53	1.16	1.39	1.54	1.73	.79	.94	1.11
21	2.05	2.28	2.53	2.78	3.03	1.59	1.75	1.97	2.19	2.40	1.10	1.28	1.46	1.65	.75	.90	1.05
22	1.96	2.18	2.42	2.65	2.89	1.52	1.67	1.88	2.09	2.30	1.05	1.22	1.40	1.58	.72	.86	1.01
23	1.87	2.08	2.31	2.54	2.77	1.45	1.60	1.80	2.00	2.20	1.00	1.17	1.34	1.51	.69	.82	.96
24	1.79	2.00	2.22	2.43	2.65	1.39	1.53	1.72	1.91	2.10	.96	1.12	1.28	1.44	.66	.79	.92
25	1.72	1.92	2.13	2.34	2.54	1.34	1.47	1.65	1.84	2.02	.92	1.07	1.23	1.39	.63	.70	.89

TABLE XIV. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

For Angles With Unequal Legs Placed With the Longer Leg Vertical

These safe loads include the weight of the angles and are figured for a maximum fibre stress of 16,000 lbs. per sq. in. and safe deflection.

For safe loads to the right of the vertical lines, the deflections will exceed the allowable limit for plastered ceilings=1/360 span.

Span in ft.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6 x4 x1	21.39	14.26	10.69	8.55	7.13	6.11	5.35	4.75	4.28	3.89	3.56	3.29	3.05	2.85	2.67	2.51	2.37	2.25	2.14
6 x4 x¾	16.66	11.11	8.33	6.66	5.55	4.76	4.16	3.70	3.33	3.03	2.77	2.56	2.38	2.22	2.08	1.96	1.85	1.75	1.66
6 x4 x½	11.56	7.75	5.78	4.62	3.85	3.30	2.89	2.57	2.31	2.10	1.92	1.78	1.65	1.54	1.44	1.36	1.28	1.21	1.15
6 x4 x⅜	8.85	5.90	4.43	3.54	2.95	2.53	2.21	1.97	1.77	1.61	1.47	1.36	1.26	1.18	1.10	1.04	0.98	0.93	0.88
6 x3½x1	20.88	13.92	10.44	8.35	6.96	5.97	5.22	4.64	4.18	3.78	3.47	3.20	2.97	2.77	2.60	2.45	2.31	2.19	2 08
6 x3½x¾	6.27	10.85	8.13	6.51	5.42	4.65	4.07	3.61	3.25	2.96	2.71	2.50	2.32	2.17	2.03	1.91	1.81	1.71	1.62
6 x3½x½	11.3	7.03	5.65	4.52	3.76	3.23	2.82	2.51	2.26	2.05	1.88	1.74	1.61	1.50	1.41	1.33	1.25	1.19	1.13
6 x3½x⅜	8.67	5.78	4.33	3.47	2.89	2.48	2.17	1.93	1.73	1.57	1.44	1.33	1.23	1.15	1.08	1.02	0.96	0.91	0.86
5 x4 x½	8.14	5.42	4.07	3.25	2.71	2.32	2.03	1.81	1.63	1.48	1.35	1.20	1.16	1.08	1.01	0.95	0.90		
5 x4 x⅜	6.24	4.16	3.12	2.50	2.08	1.78	1.56	1.39	1.25	1.13	1.04	0.96	0 89	0.83	0.78	0.73	0.69		
5 x3½x¾	11.80	7.10	5.70	4.56	3.80	3.26	2.85	2.53	2.28	2.07	1.90	1.75	1.63	1.52	1.42	1.34	1.26		
5 x3½x½	7.96	5.31	3.98	3.13	2.65	2.27	1.99	1.77	1.59	1.45	1.32	1.22	1.14	1.06	0.99	0.93	0.88		
5 x3½x⅜	6.12	4.08	3.06	2.44	2.04	1.75	1.03	1.36	1.22	1.11	1.02	0.99	0.87	0.81	0.76	0.72	0 68		
5 x3½x5/16	5.16	3.44	2.58	2.07	1.73	1.48	1.29	1.15	1.04	0.94	0.86	0.79	0.73	0.69	0.64	0.60	0.57		
5 x3 x¾	11.09	7.39	5.55	4.44	3.70	3.17	2.77	2.46	2.22	2.01	1.85	1.70	1.58	1.48	1.38	1.30	1.23		
5 x3 x½	7.75	5.17	3.88	3.10	2.58	2.21	1.94	1.72	1.55	1.41	1.29	1.19	1.11	1.03	0 97	0.91	0.86		
5 x3 x⅜	5.96	3.97	2.98	2.38	1.98	1.70	1.49	1.32	1.19	1.08	0.99	0.91	0.85	0.79	0.74	0.70	0.66		
5 x3 x5/16	5.04	3.36	2.52	2.02	1.68	1.44	1.26	1.12	1.01	0.91	0.84	0.77	0 72	0.67	0 63	0.59	0.56		
4½x3 x½	6.33	4.22	3.16	2.53	2.61	1.81	1.58	1.40	1.26	1.15	1.05	0.97	0.90	0.84	0.79	0.74	0.70		
4½x3 x⅜	4.87	3.25	2 44	1.95	1.62	1.39	1.22	1.08	0.97	0.88	0.81	0.75	0.69	0.65	0.61	0.57	0.54		
4 x3½x½	5.16	3.44	2.58	2.06	1.72	1.47	1.29	1.14	1.03	0.94	0.86	0.79	0.73	0.69	0.64				
4 x3½x5/16	3.36	2.24	1.68	1.34	1.12	0.96	0.84	0.75	0.67	0.61	0.56	0.52	0 48	0.45	0.42				
4 x3 x¾	7.15	4.76	3.57	2.86	2.38	2.04	1.79	1.59	1.43	1.30	1.19	1.10	1.02	0.95	0.89				
4 x3 x½	5.03	3.35	2.52	2.01	1.68	1.44	1.26	1.12	1.00	0.91	0.84	0.77	0.72	0.67	0.63				
4 x3 x⅜	3.89	2.59	1.94	1.55	1.29	1.11	0.97	0.86	0.78	0.70	0.65	0.60	0.55	0.52	0.48				
4 x3 x5/16	3.29	2.19	1.64	1.31	1.09	0.94	0.82	0.73	0.66	0.60	0.55	0.50	0.47	0.44	0.41				
3½x3 x¾	5.48	3.65	2.74	2.19	1.82	1.56	1.37	1.21	1.09	0.99	0.91	0.84	0.78	0.73	0.68				
3½x3 x⅜	3.00	2.00	1.50	1.20	1.00	0.86	0.75	0.66	0.60	0.54	0.50	0.46	0.43	0.40	0.37				
3½x3 x5/16	2.56	1.71	1.28	1.02	0.85	0.73	0.64	0.57	0.51	0.46	0.42	0.39	0.36	0.34	0.32				
3½x2 x⅝	4.37	2.91	2.18	1.75	1.46	1.25	1.09	0.97	0.87	0.79	0.73	0.67	0.62						
3½x2 x¼	1.94	1.29	0.97	0.77	0.64	0.55	0.48	0.43	0.39	0.35	0.32	0.30	0.27						
3 x2½x½	2.78	1.85	1.39	1.11	0.92	0.79	0.69	0.61	0.55	0.50	0.46	0.42	0.39						
3 x2½x¼	1.50	1.00	0.75	0.60	0.50	0.43	0.37	0.33	0.30	0.27	0.25	0.23	0.21						
2½x2 x½	1.87	1.24	0.93	0.75	0.62	0.53	0.47	0.41	0.37	0.34	0.31								
2½x2 x3/16	0.77	0.52	0.39	0.31	0.26	0.22	0.19	0.17	0.16	0.14	0.13								
2½x1½x7/16	1.58	1.05	0.79	0.63	0.52	0.45	0.39	0.35	0.31	0.29	0.26								
2½x1½x¼	0.97	0.64	0.48	0.39	0.32	0.27	0.24	0.21	0.19	0.17	0.16								

TABLE XV. SAFE LOADS UNIFORMLY DISTRIBUTED IN TONS OF 2000 POUNDS.

American Standard and Special Channels Set Flatwise

These safe loads include the weight of the channel and are figured for a maximum fibre stress of 16,000 pounds per sq. in.

Depth of Channel	15″ [						12″ [					10″ [					9″ [			
Wt. per ft. in lbs.	33	35	40	45	50	55	20.5	25	30	35	40	15	20	25	30	35	13.25	15	20	25
Span. 4 ft.	4.21	4.29	4.57	4.83	5.13	5.42	2.31	2.54	2.78	3.01	3.28	1.56	1.78	2.00	2.23	2.50	1.29	1.37	1.59	1.81
5	3.37	3.43	3.66	3.87	4.10	4.35	1.86	2.02	2.23	2.42	2.62	1.25	1.43	1.60	1.78	2.00	1.03	1.10	1.27	1.45
6	2.81	2.86	3.04	3.22	3.42	3.61	1.55	1.70	1.85	2.01	2.18	1.04	1.19	1.33	1.48	1.66	.86	.92	1.06	1.21
7	2.41	2.45	2.61	2.76	2.93	3.10	1.33	1.45	1.69	1.73	1.87	.89	1.02	1.14	1.27	1.42	.74	.78	.91	1.04
8	2.11	2.14	2.28	2.42	2.56	2.71	1.16	1.27	1.39	1.51	1.64	.78	.89	1.00	1.11	1.24	.65	.69	.79	.91
9	1.87	1.91	2.01	2.14	2.28	2.41	1.03	1.13	1.24	1.34	1.45	.69	.79	.89	.99	1.11	.57	.61	.70	.81
10	1.69	1.72	1.83	1.93	2.05	2.17	.93	1.02	1.11	1.21	1.31	.62	.71	.80	.89	1.00	.52	.55	.63	.73
11	1.53	1.56	1.66	1.76	1.87	1.97	.85	.92	1.01	1.10	1.19	.57	.65	.72	.81	.90	.47	.50	.58	.66
12	1.41	1.43	1.52	1.61	1.71	1.81	.78	.85	.93	1.01	1.09	.52	.59	.66	.74	.83	.43	.46	.53	.60
13	1.30	1.32	1.40	1.49	1.58	1.67	.72	.78	.86	.93	1.01	.48	.55	.61	.68	.76	.40	.42	.49	.56
14	1.20	1.23	1.30	1.38	1.46	1.55	.66	.73	.80	.86	.93	.44	.51	.57	.63	.71	.37	.39	.45	.52
15	1.12	1.14	1.22	1.29	1.37	1.44	.62	.68	.74	.80	.87	.41	.47	.53	.59	.65	.34	.37	.42	.48

Depth of Channel	8″ [					7″ [					6″ [				5″ [			4″ [		
Wt. per ft. in lbs.	11.25	13.75	16.25	18.75	21.25	9.75	12.25	14.75	17.25	19.75	8.0	10.5	13.0	15.5	6.5	9.0	11.5	5.25	6.25	7.25
Span. 3 ft.	1.40	1.54	1.69	1.81	1.97	1.12	1.26	1.40	1.54	1.71	.89	1.01	1.15	1.31	.68	.80	.96	.52	.57	.62
4	1.05	1.16	1.27	1.36	1.48	.84	.95	1.05	1.16	1.28	.65	.76	.87	.99	.50	.61	.72	.39	.43	.47
5	.84	.92	1.01	1.09	1.18	.67	.76	.84	.93	1.02	.53	.61	.69	.79	.40	.49	.58	.31	.34	.37
6	.70	.77	.85	.91	.99	.56	.63	.70	.77	.85	.44	.51	.58	.66	.33	.41	.48	.26	.28	.31
7	.60	.66	.72	.78	.85	.48	.54	.60	.66	.73	.37	.43	.50	.57	.28	.35	.41	.22	.24	.27
8	.53	.58	.63	.68	.74	.42	.47	.53	.58	.64	.33	.38	.43	.49	.25	.30	.36	.19	.21	.23
9	.47	.51	.56	.60	.66	.37	.42	.47	.52	.57	.29	.34	.38	.43	.22	.27	.32	.17	.19	.20
10	.42	.46	.51	.54	.59	.34	.38	.42	.46	.51	.26	.30	.35	.40	.20	.25	.29	.15	.17	.19
11	.38	.42	.46	.49	.54	.31	.34	.38	.42	.46	.24	.28	.31	.36	.18	.22	.26	.14	.15	.17
12	.35	.39	.42	.45	.49	.28	.32	.35	.39	.43	.22	.25	.29	.33	.16	.20	.24	.13	.14	.16
13	.32	.36	.39	.42	.40	.26	.29	.32	.36	.39	.20	.23	.27	.30	.15	.19	.22	.12	.13	.14
14	.30	.33	.36	.39	.42	.24	.27	.30	.33	.37	.19	.22	.25	.28	.14	.17	.21	.11	.12	.13

TABLE XVI. SAFE LOADS IN TONS OF 2000 POUNDS FOR C ST IRON COLUMNS WITH SQUARE ENDS.

In accordance with the New York Building Code. Columns less than 5 ins. exterior diameter and less than ¾ in. thick are not allowed in New York.

Round										Square									
Diam. in ins.	Thickness ins.	Wt. of shaft lbs./ft.	Length of Column in Feet							Sides in ins.	Thickness ins.	Wt. of shaft lbs./ft.	Length of Column in Feet.						
			8	10	12	14	16	18	20				8	10	12	14	16	18	20
5	½	22.1	33.5	31.9	30.3	28.7	27.1	25.6	24.0	5x5	½	28.1	43.8	42.0	40.3	38.5	36.8	35.0	33.2
5	⅝	27.0	40.5	38.5	36.6	34.6	32.6	30.6	28.6	5x5	⅝	34.2	53.1	51.0	48.7	46.5	44.4	42.2	40.0
5	¾	31.3	47.0	44.6	42.3	39.9	37.2	34.8	32.3	5x5	¾	39.8	61.5	59.0	56.3	53.7	51.1	48.5	45.9
5	⅞	35.5	53.0	50.2	47.5	44.8	42.0	39.3	36.6	5x5	⅞	45.1	69.4	66.3	63.3	60.5	57.1	54.0	51.0
6	½	26.9	42.5	41.0	39.4	37.8	36.1	34.6	33.0	6x6	½	34.4	55.2	53.4	51.6	49.9	48.1	46.4	44.6
6	⅝	33.0	51.6	49.6	47.9	46.0	44.0	42.1	39.7	6x6	⅝	42.0	67.1	65.0	62.8	60.6	58.4	56.2	54.0
6	¾	38.6	60.3	57.9	55.5	53.1	50.7	48.3	46.0	6x6	¾	49.2	78.4	75.8	73.1	70.6	68.0	65.3	62.6
6	⅞	44.0	68.4	65.6	62.9	60.0	57.3	54.5	51.8	6x6	⅞	56.0	89.1	86.1	83.1	80.0	77.0	74.0	70.9
6	1	49.0	76.1	73.0	69.9	66.7	63.5	60.5	57.3	6x6	1	62.5	99.1	95.7	92.2	88.8	85.3	81.8	78.4
7	½	32.0	51.2	49.6	48.0	47.0	44.8	43.3	41.7	7x7	½	40.6	66.5	64.8	62.9	61.2	59.5	57.7	56.0
7	⅝	39.1	62.8	60.6	58.6	56.7	54.7	52.7	50.8	7x7	⅝	49.6	81.3	79.1	76.9	74.7	72.5	70.3	68.1
7	¾	46.0	74.3	72.0	68.8	66.4	64.7	61.6	59.3	7x7	¾	58.6	95.3	92.8	90.2	87.5	84.9	82.3	79.6
7	⅞	53.0	84.0	81.2	78.5	75.5	72.9	70.1	67.5	7x7	⅞	67.0	109.0	105.9	102.8	99.6	96.6	93.5	90.4
7	1	58.9	94.0	90.7	87.5	84.5	81.2	78.0	76.2	7x7	1	75.0	121.9	118.1	114.8	111.3	107.5	104.2	101.0
8	¾	53.4	87.0	84.6	82.5	79.8	77.5	75.0	72.8	8x8	¾	68.0	112.2	109.6	106.9	105.7	102.0	99.0	96.4
8	⅞	61.2	99.5	96.8	94.0	91.2	88.5	85.6	83.0	8x8	⅞	77.9	128.9	125.7	122.5	119.4	116.3	113.3	110.2
8	1	68.7	111.8	108.6	105.3	102.1	98.9	95.8	93.6	8x8	1	87.5	144.1	140.9	137.1	133.9	130.1	126.8	123.2
8	1⅛	76.1	123.0	119.3	115.9	112.3	108.9	105.1	102.2	8x8	1⅛	96.7	159.0	155.1	151.2	147.3	143.5	139.5	135.7
8	1¼	82.7	134.0	130.0	126.7	122.1	118.1	114.1	111.7	8x8	1¼	105.5	173.2	169.0	164.5	160.2	155.9	151.4	149.0
9	¾	60.6	100.3	97.2	95.5	93.1	90.7	88.4	86.1	9x9	¾	77.3	129.3	126.9	124.0	121.4	118.8	116.1	113.5
9	⅞	69.8	115.1	112.2	109.5	106.9	104.0	101.2	98.4	9x9	⅞	88.9	148.3	145.3	142.2	139.0	136.1	133.0	129.9
9	1	78.5	129.0	126.0	122.9	119.8	116.6	113.3	110.2	9x9	1	100.0	167.0	163.2	159.9	156.2	152.9	149.2	146.0
9	1⅛	87.0	143.0	139.6	136.0	132.4	128.9	125.1	121.8	9x9	1⅛	110.7	184.6	180.4	176.8	172.8	168.9	164.9	161.0
9	1¼	94.9	156.1	152.2	148.3	144.5	140.5	136.6	132.8	9x9	1¼	121.1	201.5	197.0	192.8	188.2	184.0	179.7	177.1
10	¾	68.1	113.8	111.1	108.9	106.3	104.0	101.7	99.1	10x10	¾	86.7	146.1	143.5	140.9	138.3	135.7	133.0	130.1
10	⅞	78.4	130.3	127.3	124.8	122.1	119.0	116.2	113.7	10x10	⅞	99.8	168.3	165.1	162.0	159.0	155.9	152.8	149.1
10	1	88.4	147.0	143.8	142.0	137.5	134.2	131.0	128.0	10x10	1	112.5	189.5	186.0	182.2	179.0	175.3	172.0	168.4
10	1⅛	98.0	162.8	159.1	155.5	152.0	148.4	145.0	142.9	10x10	1⅛	124.8	210.0	206.1	198.1	200.3	194.3	190.5	186.3
10	1¼	107.4	178.0	174.1	170.1	166.1	162.3	158.1	154.2	10x10	1¼	136.7	230.0	225.8	221.0	216.7	212.1	208.0	203.4
11	⅞	87.1	146.1	143.1	140.4	139.0	136.1	132.0	129.1	11x11	⅞	110.8	188.1	185.0	181.9	178.7	175.8	172.7	169.5
11	1	98.2	164.5	161.4	158.1	155.0	152.0	150.3	147.1	11x11	1	125.0	211.9	208.4	204.9	201.4	197.9	194.4	190.8
11	1⅛	109.1	183.0	179.1	175.9	172.0	168.5	165.0	161.2	11x11	1⅛	138.8	235.2	231.6	227.4	223.6	219.9	215.8	211.5
11	1¼	119.7	200.3	196.3	192.6	188.3	184.3	180.4	176.5	11x11	1¼	152.3	260.5	256.0	249.2	244.4	240.2	236.0	231.6
12	1	107.5	182.1	178.9	175.6	172.4	169.5	166.3	163.1	12x12	1	137.5	234.5	231.0	227.4	224.0	220.6	217.0	213.5
12	1⅛	120.1	202.9	199.0	195.8	192.0	188.8	185.0	181.3	12x12	1⅛	152.9	260.5	256.6	252.0	248.8	244.9	241.0	236.8
12	1¼	131.9	222.7	218.5	214.4	210.6	206.4	202.7	198.9	12x12	1¼	168.0	286.3	282.0	277.8	273.4	268.9	264.3	261.0
12	1⅜	143.4	242.0	237.4	233.0	228.8	224.6	222.1	215.6	12x12	1⅜	182.5	311.0	306.0	301.9	296.6	292.0	286.8	282.0

TABLE XVII. MAXIMUM UNSUPPORTED LENGTHS FOR STANDARD SHAPES USED AS STRUTS.

Figured in accordance with the New York Building Code. The maximum length to the nearest inch does not exceed 120 times the least radius of gyration of the section.

In all cases is given the allowable load for columns with square ends and corresponding to the unsupported length.

Angles. Size	Length	Loading
8x8x1⅛	15 ft. 6 in.	68.9 tons
8x8x1 1/16	15 ft. 7 in.	65.4 tons
8x8x 15/16	15 ft. 7 in.	58.3 tons
8x8x ⅞	15 ft. 8 in.	54.6 tons
8x8x ¾	15 ft. 8 in.	47.2 tons
8x8x 11/16	15 ft. 9 in.	43.4 tons
8x8x ⅝	15 ft. 9 in.	39.7 tons
8x8x ½	15 ft. 10 in.	32.0 tons
6x6x1	11 ft. 7 in.	50.3 tons
6x6x ⅞	11 ft. 7 in.	44.5 tons
6x6x ¾	11 ft. 8 in.	37.2 tons
6x6x 11/16	11 ft. 8 in.	34.2 tons
6x6x ⅝	11 ft. 8 in.	31.3 tons
6x6x 9/16	11 ft. 9 in.	28.3 tons
6x6x ½	11 ft. 9 in.	25.3 tons
6x6x 7/16	11 ft. 10 in.	22.3 tons
6x6x ⅜	11 ft. 10 in.	19.2 tons
5x5x1	9 ft. 6 in.	37.2 tons
5x5x ⅞	9 ft. 6 in.	35.3 tons
5x5x 13/16	9 ft. 7 in.	31.1 tons
5x5x ⅝	9 ft. 7 in.	24.4 tons
5x5x ½	9 ft. 9 in.	19.6 tons

Angles. Size	Length	Loading
5 x5 x 7/16	9 ft. 9 in.	17.3 tons
5 x5 x⅜	9 ft. 10 in.	14.9 tons
4 x4 x⅞	7 ft. 8 in.	25.7 tons
4 x4 x⅝	7 ft. 8 in.	19.1 tons
4 x4 x 9/16	7 ft. 9 in.	17.4 tons
4 x4 x½	7 ft. 9 in.	15.5 tons
4 x4 x 7/16	7 ft. 9 in.	13.7 tons
4 x4 x⅜	7 ft. 10 in.	11.9 tons
4 x4 x 5/16	7 ft. 10 in.	10.0 tons
3½x3½x¾	6 ft. 8 in.	19.4 tons
3½x3½x⅝	6 ft. 8 in.	16.5 tons
3½x3½x½	6 ft. 9 in.	13.5 tons
3½x3½x 7/16	6 ft. 9 in.	11.9 tons
3½x3½x⅜	6 ft. 10 in.	10.3 tons
3½x3½x 5/16	6 ft. 10 in.	8.6 tons
3 x3 x½	5 ft. 9 in.	11.4 tons
3 x3 x⅜	5 ft. 9 in.	8.7 tons
3 x3 x¼	5 ft. 10 in.	5.9 tons
3 x3 x 5/16	5 ft. 10 in.	7.4 tons
2½x2½x⅜	4 ft. 9 in.	7.2 tons

I-Beams. Size	Length	Loading
3 in. I 5½ lbs.	5 ft. 3 in.	6.7 tons
4 in. I 7½ lbs.	5 ft. 10 in.	9.2 tons
5 in. I 9¾ lbs.	6 ft. 6 in.	11 9 tons
6 in. I 12¼ lbs.	7 ft. 2 in.	14.9 tons
7 in. I 15 lbs.	7 ft. 9 in.	18.3 tons
8 in. I 18 lbs.	8 ft. 4 in.	22.1 tons
9 in. I 21 lbs.	9 ft. 0 in.	26.0 tons
10 in. I 25 lbs.	9 f.t 8 in.	30.4 tons
12 in. I 31½ lbs.	10 ft. 1 in.	38.2 tons
15 in. I 42 lbs.	10 ft. 9 in.	51.6 tons
18 in. I 55 lbs.	11 ft. 6 in.	65.6 tons
20 in. I 65 lbs.	12 ft. 1 in.	78.7 tons
24 in. I 80 lbs.	13 ft. 7 in.	96.1 tons
Channels.		
3 in. [4 lbs	4 ft. 1 in.	4.9 tons
4 in. [5¼ lbs.	4 ft. 6 in.	6 5 tons
5 in. [6½ lbs.	5 ft. 0 in.	8.0 tons
6 in. [8 lbs.	5 ft. 4 in.	9.9 tons
7 in. [9¾ lbs.	5 ft. 10 in.	11.8 tons
8 in. [11¼ lbs.	6 ft. 3 in.	13.9 tons
9 in. [13¼ lbs.	6 ft. 8 in.	16.1 tons
10 in. [15 lbs.	7 ft. 2 in.	18.4 tons
12 in. [20½ lbs.	8 ft. 1 in.	24.8 tons
15 in. [33 lbs.	9 ft. 1 in.	40.8 tons

TABLE XVIII. CYLINDRICAL TANKS.

Diameters in feet and inches; areas in sq. ft.; capacity in U. S. gallons for one foot in depth; weight in pounds for one foot in depth; cubic feet for one foot in depth. 1 gallon=231 cubic inches=0.1337 cu. ft.

Diam. Ft.	Diam. In.	Area Sq. ft.	Gals. for 1 ft. depth	Weight pounds	Diam. Ft.	Diam. In.	Area Sq. ft.	Gals. for 1 ft. depth	Weight pounds	Diam. Ft.	Diam. In.	Area Sq. ft.	Gals. for 1 ft. depth	Weight pounds
5		19.63	146.83	1227	8	4	54.54	407.98	3414	11	8	106.90	799.61	6680
5	1	20.29	151.78	1270	8	5	55.64	416 21	3480	11	9	108.43	811.14	6780
5	2	20.97	156 86	1310	8	6	56.75	424.48	3548	11	10	109.98	822.65	6870
5	3	21.65	161.95	1354	8	7	57.86	432.81	3614	11	11	111.53	834.24	6970
5	4	22.34	167.11	1395	8	8	58.99	441.26	3682	12		113.10	846.03	7060
5	5	23.04	172.38	1440	8	9	60.13	449.82	3761	12	1	114.67	857.73	7160
5	6	23.76	177.72	1482	8	10	61.28	458.41	3834	12	2	116.26	869.63	7265
5	7	24.48	183.15	1560	8	11	62.44	467.08	3900	12	3	117.86	881.65	7360
5	8	25.22	188.66	1578	9		63.62	475.89	3978	12	4	119.47	893.63	7475
5	9	25.97	194.25	1625	9	1	64.80	484.73	4050	12	5	121.09	905.76	7560
5	10	26.73	199.92	1670	9	2	65.99	493.63	4124	12	6	122.72	918.00	7665
5	11	27.49	205.67	1720	9	3	67.20	502.70	4200	12	7	124.36	930.22	7770
6		28.27	211.47	1770	9	4	68.42	511.81	4275	12	8	126.01	942.56	7875
6	1	29.06	217.38	1818	9	5	69.64	520.94	4350	12	9	127.68	955.09	7980
6	2	29.87	223.43	1868	9	6	70.88	530.24	4425	12	10	129.35	967.54	8090
6	3	30.68	229.50	1920	9	7	72.13	539.56	4510	12	11	131.04	980.19	8195
6	4	31.50	235.63	1970	9	8	73.39	548.98	4586	13		132.73	992.91	8295
6	5	32.34	241.91	2020	9	9	74.66	558.51	4665	13	1	134 44	1005.62	8410
6	6	33.18	248.20	2072	9	10	75.94	568.06	4750	13	2	136.16	1025.22	8510
6	7	34.04	254.63	2126	9	11	77.24	577.79	4828	13	3	137.89	1031.05	8610
6	8	34.91	261.13	2181	10		78.54	587.52	4905	13	4	139.63	1044.44	8730
6	9	35.78	267.69	2239	10	1	79.85	597.30	4990	13	5	141.38	1057.52	8845
6	10	36.67	274.30	2290	10	2	81.18	607.27	5075	13	6	143.14	1070.80	8950
6	11	37.57	281.03	2342	10	3	82.52	617.26	5155	13	7	144.91	1083.92	9055
7		38.48	287.88	2406	10	4	83.86	627.31	5242	13	8	146.69	1097.24	9170
7	1	39.41	294.79	2461	10	5	85.22	637.49	5328	13	9	148.49	1110.80	9290
7	2	40 34	301.74	2520	10	6	86.59	647.74	5415	13	10	150.29	1124.19	9405
7	3	41.28	308.81	2580	10	7	87.97	658.05	5500	13	11	152.11	1137.80	9510
7	4	42.24	315.96	2640	10	8	89.36	668.45	5580	14		153.94	1151.50	9620
7	5	43.20	323.14	2700	10	9	90.76	678.95	5670	14	1	155.78	1165.26	9730
7	6	44.18	330.48	2762	10	10	92.17	689.47	5760	14	2	157.62	1179.02	9850
7	7	45.17	337.87	2824	10	11	93.60	700.17	5850	14	3	159.48	1193.00	9970
7	8	46.16	345.28	2883	11		95.03	710.90	5945	14	4	161 35	1206.92	10100
7	9	47.17	352.88	2944	11	1	96.48	721.71	6030	14	5	163.24	1221.07	10210
7	10	48.20	360 54	3016	11	2	97.93	732 55	6122	14	6	165.13	1235.30	10340
7	11	49.22	368.17	3079	11	3	99.40	743.58	6210	14	7	167.03	1249.41	10450
8		50.27	376.01	3140	11	4	100.88	754.58	6300	14	8	168.95	1263.77	10580
8	1	51.32	383.89	3210	11	5	102.37	765.72	6400	14	9	170.87	1278.20	10685
8	2	52.38	391.82	3274	11	6	103.87	776.99	6485	14	10	172.81	1292.64	10800
8	3	53.46	399.88	3340	11	7	105.88	791.98	6590	14	11	174.76	1307.24	10930

TABLE XIX. DECIMALS OF AN INCH FOR EACH 1/32ND.

Inch.	Inch.	Inch.	Inch.
1/32	.031	17/32	.531
1/16	.062	9/16	.562
3/32	.094	19/32	.594
1/8	.125	5/8	.625
5/32	.156	21/32	.656
3/16	.187	11/16	.687
7/32	.219	23/32	.719
1/4	.250	3/4	.750
9/32	.281	25/32	.781
5/16	.312	13/16	.812
11/32	.344	27/32	.844
3/8	.375	7/8	.875
13/32	.406	29/32	.906
7/16	.437	15/16	.937
15/32	.469	31/32	.969
1/2	.500	1	1.000

TABLE XX. DECIMALS OF A FOOT FOR EACH 1/16TH OF AN INCH.

Inch.	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1/8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16	.0573	.1406	.2240	.3073	.3906	4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8	.0729	.1562	.2396	.3229	.4062	4896	.5729	..6562	.7396	.8229	.9062	.9896
15/16	.0781	.1615	.2448	.3281	.4115	4948	.5781	6615	.7448	.8281	.9115	.9948
1												1.0000

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